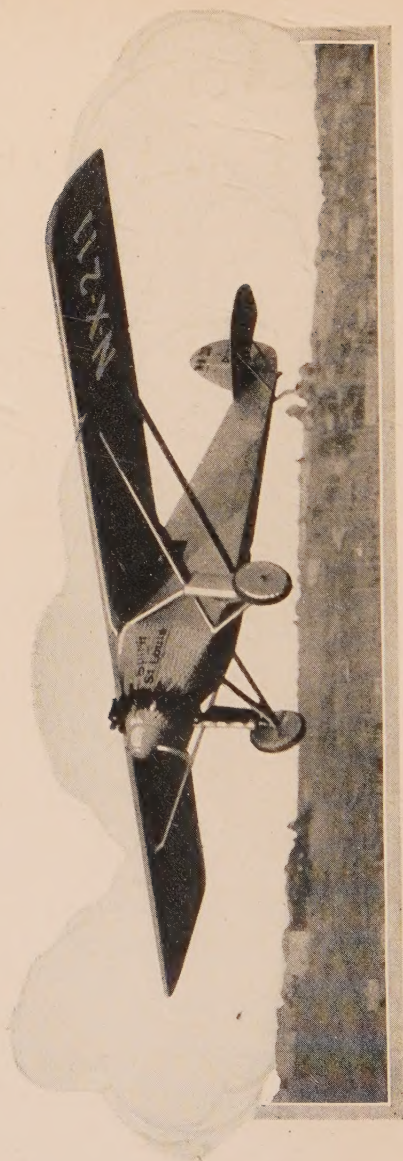


B H Cowsky



Digitized by the Internet Archive
in 2023 with funding from
Kahle/Austin Foundation

AIRCRAFT HANDBOOK



The world's most famous airplane. Colonel Charles A. Lindbergh's "Spirit of St. Louis."

THE AIRCRAFT HANDBOOK

A COLLECTION OF FACTS AND SUGGESTIONS CONCERNING
THE CONSTRUCTION AND CARE OF PLANES, MOTORS
AND INSTRUMENTS FOR THOSE INTER-
ESTED IN MODERN AIRCRAFT

BY

FRED H. COLVIN

*Member American Society of Mechanical Engineers and Franklin Institute;
Editor of the American Machinist, Author of "Machine Shop
Arithmetic," "Machine Shop Calculations,"
"American Machinists' Hand Book."*

AND

HENRY F. COLVIN

Member Franklin Institute.

FOURTH EDITION

McGRAW-HILL BOOK COMPANY, INC.

NEW YORK: 370 SEVENTH AVENUE

LONDON: 6 & 8 BOUVERIE ST., E. C. 4

1929

COPYRIGHT, 1918, 1921, 1928, 1929, BY THE
MCGRAW-HILL BOOK COMPANY, INC.

PRINTED IN THE UNITED STATES OF AMERICA

THE MAPLE PRESS COMPANY, YORK, PA.

PREFACE

The developments in aviation since the last edition have made obsolete much that was published at that time. Some engines then illustrated are now omitted as they are no longer a factor in commercial air transport. The Curtiss OX-5 engine is, however, retained because it is still widely used on small planes. These engines are, in fact, receiving greater care than was formerly the case. Similarly, the Hispano-Suiza or Hisso is still used though neither are now manufactured.

Many new engines are under development and some have won their place. These are described in some detail. Others will doubtless be securely established before the next edition.

The planes illustrated were selected to give a general idea of the types now in use in this country as it is obviously impossible to show all that are being built. Accessories such as instruments, engine starters, landing gears, and the like are selected to show types that have proved successful. In magnetos, for example, the type shown is used on nearly every engine built in this country. The same is true of some other accessories, so that what may seem like excessive mention of a few makes is because there are few others in these particular fields.

Much new material has been added, notably in the sections devoted to Construction and to Materials. We believe that both sections will prove of value both by builders and by those who repair planes at various airports.

Manufacturers and others have been generous in supplying information for the benefit of the industry and their assistance is gratefully acknowledged. Suggestions as to making this volume of even greater value to the airplane industry will be appreciated.

THE AUTHORS.

NEW YORK, N. Y.
September, 1929.

INTRODUCTION

Aviation has advanced in every way since the publication of the last edition. Feats that were dreams or predictions have become history. Both the continents and the oceans have been spanned, planes have been fueled in mid air enabling all previous endurance records to be far exceeded. Cans of fuel have been picked up from the ground by a flying plane. The air mail has been extended widely and carries on, day and night, in all weather and with remarkably few delays and fatalities. Passenger carrying is increasing and some of the transport lines have begun to pay dividends. Airports are growing in number and are being improved as to size, surface, and the accommodations for air passengers.

From the tropics to the poles the airplane is playing an important part in exploration, making possible extended observations in a fraction of the time required by any other methods. Metals are becoming a large factor in aircraft construction, and this involves, even though indirectly, many metal-working industries. The demand for aircraft engines is resulting in the enlargement of old plants and the development of new ones, accompanied by a constant search for better designs and improved performance. The Diesel type of engine is being tested in actual flights and there is a general development in all lines pertaining to aircraft.

The aircraft industry is becoming established and will take its place with other industries devoted to furnishing modern transportation methods.

CONTENTS

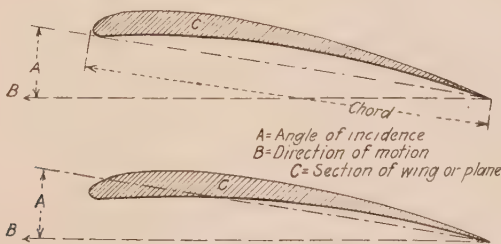
	PAGE
PREFACE.	vii
INTRODUCTION	ix
 SECTION	
I. SIMPLE AIRPLANE THEORY.	1
II. TYPES OF AIRPLANES.	10
III. RIGGING AND SERVICING THE PLANE	34
IV. THE AIRPLANE ENGINE.	67
V. TROUBLE SHOOTING FOR AIRPLANE ENGINES	280
VI. THE PROPELLER	303
VII. ENGINE AND PLANE ACCESSORIES	317
VIII. AIRCRAFT INSTRUMENTS.	372
IX. AIRPLANE CONSTRUCTION	397
X. MATERIALS FOR AIRCRAFT CONSTRUCTION.	429
XI. S. A. E. STANDARDS	493
XII. AIRSHIPS OR DIRIGIBLE BALLOONS	534
XIII. CONSTRUCTION OF AIRPORT	544
XIV. AIR COMMERCE REGULATIONS	589
XV. NOMENCLATURE FOR AERONAUTICS.	630
INDEX.	683

THE AIRCRAFT HANDBOOK

SECTION I

SIMPLE AIRPLANE THEORY

Aviation has become a vital factor of growing importance in national transport of mail, express, and passengers. The general public, stirred primarily by the flight of Col. Charles Lindbergh from New York to Paris, is becoming airminded and desires to understand the fundamental principles of flight in a general way. For those who are more deeply interested in the theory of flight, but who do not wish to study all its scientific aspects, a simple explanation is given in this chapter.



FIGS. 1 and 2.—Measuring angle of incidence.

An airplane is supported in the air by driving it so that the air is forced under its inclined surfaces. These surfaces force the air down and the reaction of the air supports the plane. The inclination of these surfaces is called the *angle of incidence* and is measured when the plane is level or in its normal flying position, which is parallel with the shaft of the engine. In the side view of the surface shown (Fig. 1) the angle of incidence is that formed between the horizontal or line of motion and the chord, or straight line from one side of the wing to the

other. This chord is the effective width of the wing. A more correct definition of the angle of incidence is the angle formed between the direction of motion and the neutral lift line, which starts at the trailing edge of the wing and runs along its main lifting surface, neglecting the downward curve of the front edge. The two methods are shown in Figs. 1 and 2. From a practical viewpoint the former is sufficient and enables the rigger to measure the angle more accurately than the other way.

The angle of incidence varies considerably on different types of machines and is determined largely by the performance required of the machine.

THE LIFT OF THE WINGS

The lift, secured by forcing the plane through the air, is due both to the direct reaction of the air against the lower surfaces of the plane and to the partial vacuum over the top of the wings, as at *A*, Fig. 3. This vacuum is found to give over half the lifting force, it is, in fact, usually

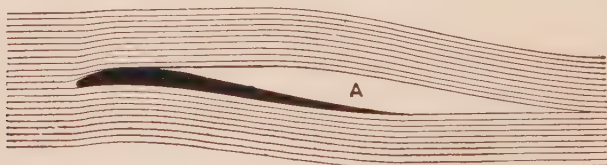


FIG. 3.—Action of air on wing.

considered that about 60 per cent of the lifting power comes from the upper surfaces of the wings. This makes it necessary to pay particular attention to the condition of the upper wing surfaces as they are even more important than the lower surfaces.

Action of Airfoils.—The effect of the passage of an airfoil, or wing section, through the air is shown in Fig. 4, from publications of the U. S. Army Air Corps. These six views show how the air currents act as they pass over the wing surfaces. As will be seen, the air leaving the top of the wing is more disturbed as the angle of attack is increased, and that the air leaving the trailing edge flows downward.

Many wing sections have been developed by careful experimentation, so as to secure the best results in planes for various services. Sections

have been developed to secure great speed, heavy lift, and for extreme safety. Much work of this kind has been done in England, France, and Germany, while the National Advisory Committee for Aeronautics in this country has done splendid work at its great testing laboratory at Langley Field, Va.; this being equipped with a huge wind tunnel

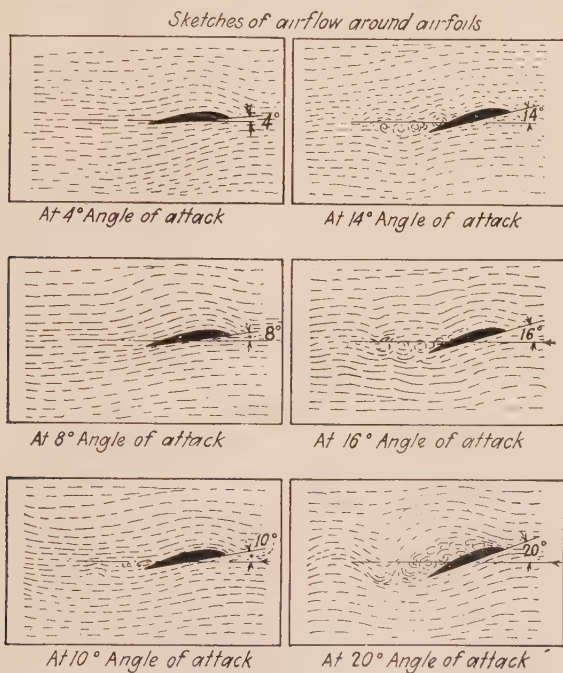


FIG. 4.—Airflow around airfoil at different angles.

and other apparatus. Each country has developed wing sections or "airfoils" which have a special name to denote their origin. Recent developments have made the use of extremely thick wings very practical. These wings are so thick that they can be internally braced, so that no struts or guy wires are required to brace them, thus reducing parasite, or useless resistance, to a minimum. The Ford wing, for example, is 32 inches thick (see p. 20), and another builder contemplates a wing 9 feet thick.

It is interesting to note that the thick wing section has proved remarkably efficient in many cases. The first development of this type of wing was begun by Dr. Hugo Junkers in Germany and was soon followed by Anthony Fokker, after flying Junker planes. The thick wing compares favorably with the thin sections for low drag at small angles of attack and also with the highly cambered thin sections for high lift at the higher angles of attack. It is a good compromise section offering the additional advantage of reducing parasite resistance of struts and wires by enabling sufficient strength to be built inside the wing itself.

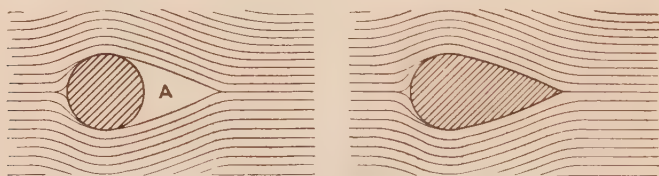


FIG. 5.—How air forms around struts.

The efficiency of the machine itself, without regard to the engine which drives it, is due to the relation between the lift and the resistance or drift, this being known as the *lift-drift ratio*. The less the resistance the greater the efficiency of the machine, so that every effort is made to decrease the resistance by stream-lining all parts which are exposed. This stream-lining is making the piece pointed not so much where it enters the air as where the air leaves it, as the passing air acts in the same way over the top of the wing and creates a partial vacuum which holds back the piece and adds to the resistance. This is decreased by making the shape of the piece as shown in Fig. 5, which shows the effect of both round and stream-lined shapes. The space *A* shows the difference in vacuum created. It is for this reason that the landing wheels are covered and the exposed wires are stream lined.

The camber of the wings is the curved surfaces at the top and bottom, the top being convex and the bottom either concave or convex. This camber varies greatly with the machine, and the rigger can only assume that this, as with the angle of incidence, is rightly proportioned and keep it in the condition in which he finds it. This is also true of the stagger of the planes, the rigger's work being to see that the proportions

of the designer are maintained. The amount of stagger is sometimes given in inches, while other makers state it in degrees.

DIHEDRAL ANGLE

The dihedral angle, or the angle which the wings make with the horizontal, is to secure an inherent stability or self-righting quality to the machine. An exaggerated example of this is shown in Fig. 6, which shows the machine level at *A* and tipping at *B*. As soon as the

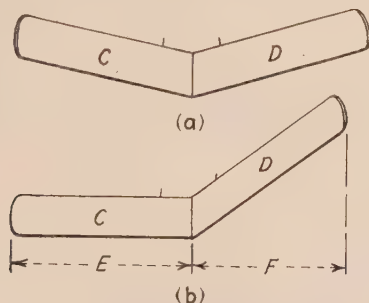


FIG. 6.—Action of dihedral wings.

plane starts to tip, the wing *C*, which goes down, immediately presents more surface to the air while the other wing *D* decreases its surface and the machine at once starts to right itself. The supporting area of each is represented by *E* and *F*.

THE SLOTTED WING

One of the interesting developments in airplane construction is known as the slotted wing, its object being to increase the safety of planes in preventing dangerous spins and in landing. Apparently experiments along this line were made in both England and Germany at about the same time but the device has not as yet come into very general use in either country. The greatest developments in this line have been made under the direction of Capt. F. Handley Page, and both the Moth, a small plane, and the Villiers, a large French plane, are being built with slots in the wings. A close view of the auxiliary front wing which forms the slot when in the position shown, can be

seen in Fig. 7, while the Villiers plane with slots closed is illustrated in Fig. 8. A few other planes also use the slotted wing.

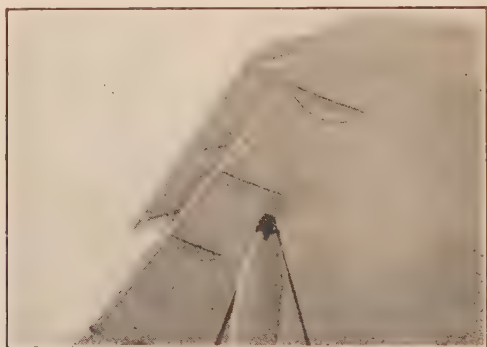


FIG. 7.—Slotted wings of moth plane.



FIG. 8.—Villiers plane with slots closed.

Quoting from *Circular 87* of the N. A. C. A.:

The slotted wing, which has been undergoing development for several years in England under the direction of F. Handley Page, constitutes one

of the most important devices from the viewpoint of safety in flight. It is known that above a certain angle of attack (the critical angle) there is a separation of the air filaments on top of the wing, which results in a diminution of the lift accompanied by a considerable increase in the drag. If the ailerons are operated at that instant, the drag is still further increased, and stalling occurs with all its well-known consequences.

The introduction of a slot into the leading edge of the wing results in considerably increasing the critical angle of attack. The lift is also greatly increased (sometimes nearly 100 per cent) for angles of attack up to 25 and 30 degrees instead of the usual 14 to 16 degrees. The natural result is a

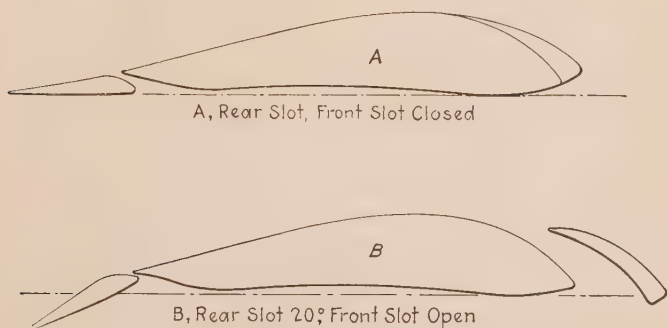


FIG. 9.—F. Villiers A-5 airfoil open and closed.

great reduction in the minimum speed, as likewise in the take-off run and landing run. When the slot is closed, the profile is like the ordinary profile and behaves the same.

Experimentation with the device led to combining it with a rear flap, which is operated simultaneously with the front flap. The tests showed that it was possible to render the operation of the flaps entirely automatic and thus obtain an automatic lateral control. Test flights demonstrated on many occasions that an airplane, nosed up beyond the critical angle, descended vertically and then began a dive without slipping off on the wing or going into a spin.

The extreme position of the flaps governing the slots of the Villiers plane, with the F. Villiers A-5 airfoil, are shown in Fig. 9. The flaps on the Moth plane are also automatic in operation and so controlled by levers as to open uniformly along their length. The slots should

be approximately five-eighth of the length of the wing for most satisfactory results.

We quote F. Handley Page regarding the status of the slotted wing:

The inherent and fundamental difficulty of the breakdown of air flow over the upper surface of a wing section—known as “burbling”—has, due to the stalling of a normal unslotted wing, placed a lower safe limit on the flying speed of an aircraft; and it has likewise set a lower limit, below which, owing to lack of increased lift with increased angle, the aircraft controls cease to respond to the control movements of the pilot.

The increased range of angles at which lift can be obtained with the slot is limited only in degree by the number of slots used. Its ultimate development must depend on mechanical considerations, and it may well be that, with further mechanical experience, which is gained but slowly, larger numbers of slots will be used in a wing, particularly now that the fashion for their use has set in; for fashion and custom, as in all the arts and commerce, settle to a very large extent the choice of the pilot and the decisions of the engineer.

Two courses lie open to a designer in the application of the slot. The first and most obvious is to slot the wing throughout its span, and as the range of angles is increased through which useful lift can be exerted upon the aircraft, to obtain a wider speed range and improved performance, provided that the mechanism added does not offset the advantage so gained. The second course is to apply the slot to a portion only of the lifting surfaces and to use the device mainly to give that control at and beyond the stalling speed of the aircraft which is lacking with the ordinary wing.

In the research work detailed, certain salient features may be summarized:

1. With thick wing sections an increase in lift coefficient can be obtained by the use of the slot equal in magnitude to that with thin wings.

2. As the use of the slot for control purposes is dependent on the lift increase obtained a similar result in stalled flight can be obtained with both thick and thin sections.

3. Where the aerofoil is used for a portion of the span only the best result for control is obtained when the auxiliary aerofoil is fitted in an intermediate position between the tip and the center of the wing.

4. With a correctly designed and positioned auxiliary aerofoil opening and closing automatically a very good control at and beyond the stall can be obtained without the added complication of control by the forward aerofoil.

5. If increased control is required at and beyond the stall, particularly at very high angle of incidence, the controlled slot or interceptor should be used.

In making a survey of the results it must be remembered that these tests show rolling and yawing moments on an aerofoil proceeding on a level keel and do not show righting moments in a roll. It is obvious that it would be impossible to use the unslotted control in free flight at the large angles measured without setting up auto rotation, whereas the damping in roll with the slotted tips permits of the use of the controls in the normal way.

In the perfecting of the slotted wing, a wide field is open to those who delight in the exploration of new avenues of scientific research and engineering development. To such the multi-slotted aerofoil with its steady air flow up to large angles of incidence offers every inducement and every possibility.

It is particularly fitting that we should deal with such problems of control for in so doing we continue to develop that branch of the flying art of which the foundations were so well and truly laid by the pioneer work of Orville and Wilbur Wright.

SECTION II

TYPES OF AIRPLANES

Airplanes may be divided into two general types, biplanes and monoplanes, for, although planes with more than two wings have been built and flown, only the two mentioned have survived, with a tendency for more monoplanes than formerly. Many biplanes now use wings of practically equal length, or spread, but these vary, usually toward a longer upper wing but not in all cases. An exception is the "sesqui" or short underwing, less than half the length (Fig. 3) of the upper wing. One object of this construction is to obtain a substantial support for the bracing of the upper wing, this being accomplished by making the lower wing a cantilever beam and supporting the upper wing from the ends of the lower or half wing.

There are three types of monoplanes, known as the "high-wing, mid-wing, and low-wing monoplanes." As the names imply, the location of the wings gives the name of the type. The high-wing monoplane is most popular at present, but there are more low-wing planes being built than formerly. The mid-wing plane has not, as yet, found great favor owing to the structural problems involved. Where high wings are supported above and clear of the fuselage they are sometimes known as "parasol" planes.

Both high-wing and low-wing planes are built with cantilever wings and with braced wings as well, the latter being a new development in the case of the low-wing plane. The cantilever type of wing requires no external bracing, its construction including all necessary strength within the wing itself. In the case of all metal wings, such as the Ford, the wing covering itself adds strength to the structure, making it, in effect, a large metal tube of special cross-section. The same things hold good to a degree, with the Fokker wing where the entire outer covering of the wing is of wood veneer. With cloth-covered wings, however, the required strength must be in the wing beams, ribs and bracing.

With the cantilever type of wing there is no external bracing to offer resistance to the wind. Most high-wing monoplanes, however, use the braced wing, the braces running from a suitable point under the wing to the bottom of the fuselage structure; the load on the braces being taken by a cross-member under the fuselage. Some low-wing planes are also resorting to braces, these going from the wing to the upper part of the fuselage structure. This is not considered by some engineers to be as good a construction method as the other, but only time and experience will tell which is to survive.

With the mid-wing type of monoplane the cantilever construction can only be used by special fuselage design, and bracing at both top and bottom is usual. Here again, only experience will give us the outcome.

There are no fixed opinions as to the relative advantages of the different types of planes. In general, however, it seems safe to say that the biplane has a slower speed in taking-off, in the air and in landing, than the monoplane, power and other conditions being equal. The biplane seems to be a littler better suited for load carrying and landing and taking-off in small fields. The monoplane, on the other hand, is faster, owing to less wind resistance, but landing at higher speed, must have a larger landing field than a biplane of equal capacity.

In general, according to Chief Engineer Wright of the Curtiss Company, the biplane can be built lighter than a monoplane, because of better trussing arrangement, and is likely to exceed in airfoil efficiency. It falls short, however, in general aerodynamic efficiency and in overall fineness, which he feels gives the monoplane the advantage, particularly when cantilever or internally braced wings are used. The biplane has the advantage of compactness owing to the smaller span that is possible. He considers the externally braced monoplane as a compromise between the biplane and internally braced monoplane. The externally braced monoplane is an American development and has much to commend it. Among the disadvantages of the biplane is the use of brace wires on which ice frequently collects to a dangerous extent.

Each type of monoplane has its advocate. The high wing is less liable to damage and gives full vision beneath the plane, in all directions. Upward vision is, however, not so good, and this is a disadvantage in watching for other planes in taking-off and in landing. The low-wing plane gives perfect vision overhead and, as usually constructed, all the

vision below that is necessary; the view being clear ahead of the pilot's seat.

Another advantage is claimed for the low wing, that of assisting a landing by the cushion of air between the wing and the earth. In some experimental planes, the angle of the wing has been made sufficient to have this air cushion act as an effectual brake in landing. In order to avoid damage to the wings in landing in rough country it is customary to give the wings considerable dihedral angle, which also assists in making the plane stable. Although comparatively few low-wing planes have been built in this country, the type has proved very suc-

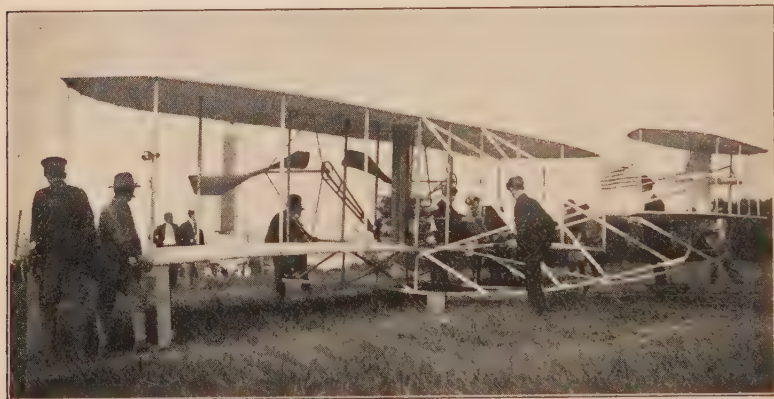


FIG. 1.—Wright plane at Fort Myers, 1908.

cessful abroad. New planes of this type are now under way by American builders.

Examples of the various types of planes will be found on pages 16 to 30.

In view of the development that has taken place in aviation since the Wright brothers first flew at Kitty Hawk it is well to look back to the early planes, such as the early Wright machine in Fig. 1, which was flown at the Army trials at Fort Myers, near Washington in 1908 and compare it with the later planes, some of which are being built in comparatively large quantities. With skids for landing gear and launched with a sort of catapult, with two pusher propellers running in opposite directions, one having a crossed chain for that purpose, and controls in front except for the warping of the wings as ailerons,

these machines not only flew, but flew so well that skeptics were convinced and the airplane had begun to work its way into the world's transportation system.



FIG. 2.—Cierva Autogiro in flight.



FIG. 3.—Bellanca "Sesqui" plane, Roma.

Inventors have dreamed of planes that would rise vertically and so eliminate the necessity for long landing fields, and helicopters of various types have been tried, without noticeable success. A modi-

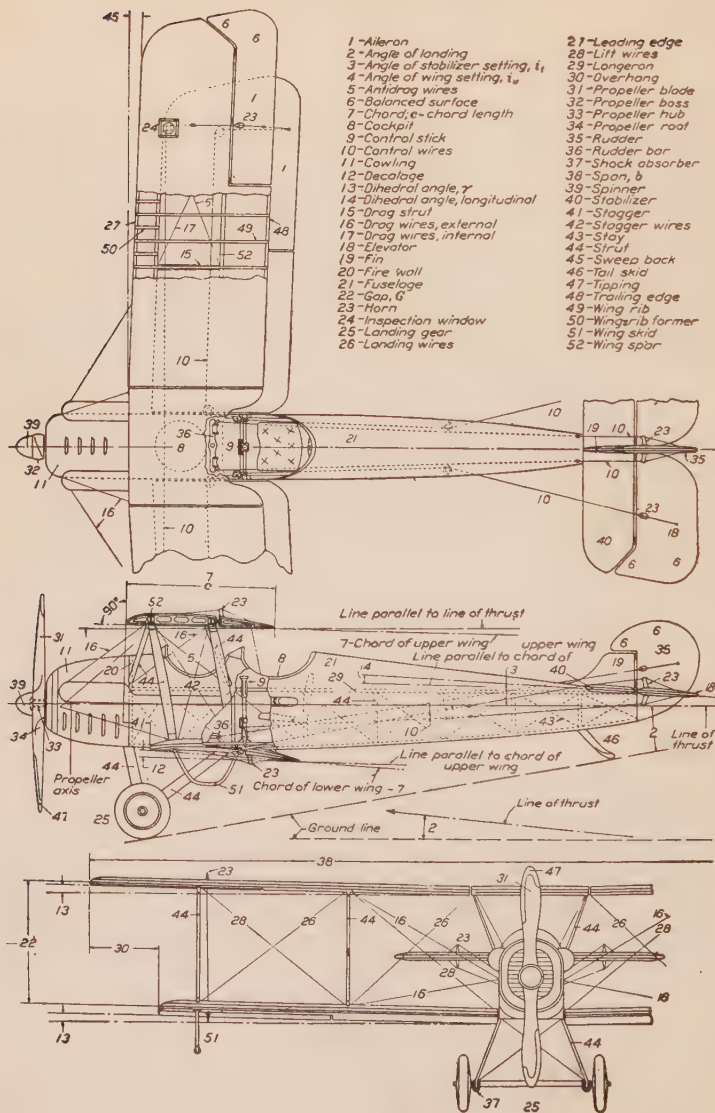


FIG. 4.—Typical biplane with parts named.

fication of the helicopter has, however, made several successful flights in Europe, and in this country, the plane being shown in Fig. 2. This plane, which is known as the Cierva Autogiro, does not rise vertically, nor does it get into the air quickly, but it lands in a comparatively small field. It has a small low wing and the usual propeller in front. The main support in the air, however, comes from the revolving wings that are in the form of a large four-bladed propeller. This propeller is not driven by the engine as might be supposed, but turns freely in the air when the machine is in flight. In starting it is necessary to get the revolving wings in motion either by hand, with a motor, or by taxiing around the field until they revolve fast enough to perform their lifting and sustaining function. It is still an experiment. Other experiments are being tried, such as biplanes with wings whose relative positions can be changed in flight or in landing so as to more or less control speed both in the air and in landing, which is still the major problem of flying. Structural changes are also taking place in planes of standard designs, and many changes are yet to come.

A careful study of the diagram, Fig. 4, will give a good general idea of the construction of the average biplane and show the terms used to designate different parts. It will also indicate what is meant by such terms as "sweep back," "dihedral," "stagger," and other terms in general use. A study of the various planes illustrated will show the wide difference in design and in the arrangement of the wings and other parts. It will be of especial interest to note the change since the first Wright plane as shown.

COMMERCIAL AIRPLANES

The commercial airplane, in the terse language of William B. Stout:

... must support itself in the air financially as well as mechanically. Unless it can pay a dividend it has no place in business. Heavy loads at high speed with low horsepower are necessary, if this combination can be secured with safety. But the safety fundamental must be solved before pay load per horsepower can be considered.

Here is where opinions differ as to single- or multimotored planes. Single-motored planes are probably somewhat more efficient in load-carrying capacity than planes having three motors, which accounts for the large number of single-motored planes in use. Many feel, however,



FIG. 5.—Aeromarine-Klemm AKL-26.

Wing span, 40 feet
 Wing area, 210 square feet
 Weight empty, 935 pounds
 Useful load, 595 pounds
 Pay load, 232 pounds

High speed, 95 m.p.h.
 Cruising speed, 85 m.p.h.
 Landing speed, 37 m.p.h.
 Rate of climb, 450 feet per minute
 Cruising range, 510 miles



FIG. 6.—Bellanca CH plane.

Wright Whirlwind engine
 Wing span, 46 feet, 4 inches
 Length, 27 feet, 9 inches
 Height, 8 feet, 6 inches
 Wing chord, 6 feet, 7 inches
 Wing area, 273 square feet
 Aileron area, 26 square feet
 Stabilizer area, 27 square feet
 Fin area, 7 square feet
 Elevator area, 17 square feet
 Rudder area, 15 square feet
 Weight empty, 2,000 pounds
 Pay load, 1,300 pounds
 Total with fuel, pilot etc., 4,050 pounds

Fuel capacity, 90 gallons
 Oil, 6 gallons
 Miles per gallon cruising speed, 9.5 gallons
 Maximum speed, 126 m.p.h.
 Cruising speed, 105 m.p.h.
 Landing speed, 46 m.p.h.
 Range, maximum speed, 600 miles, with 90 gallons of fuel
 Range, cruising speed, 800 miles. With 90 gallons of fuel
 Range, economical speed, 900 miles. With 90 gallons of fuel
 Ceiling, absolute, 16,000 feet
 Service ceiling, 15,000 feet



FIG. 7.—Boeing passenger transport.

Upper wing span, 80 feet
 Upper wing chord, 120 inches
 Lower wing chord, 84 inches
 Stagger, 8 degrees
 Dihedral angle, 2 degrees
 Length, overall, 55 feet
 Height, overall, 14 feet, 8 inches
 Wing area, with ailerons, 1,200 square feet
 Total aileron area, 107 square feet
 Total stabilizer area, 79 square feet
 Total elevator area, 67 square feet
 Rudder area, 36 square feet

Fin, 25.6 square feet
 Weight empty, 9,229 pounds
 Useful load, 6,045 pounds
 Number of passengers, 12
 Weight loaded, 15,274 pounds
 High speed, 128 m.p.h.
 Landing speed, 55 m.p.h.
 Wing load, 12.5 pounds per square foot
 Power load, 9.69 per horsepower
 Power equipment, three Hornet engines, 525
 horsepower each



FIG. 8.—Curtiss Robin.

Wing span, 41 feet
 Length, 25 feet, 9 inches
 Height, 7 feet, 10 inches
 Wing area, 245 square feet
 Weight, 1,489 pounds
 Pay load, 328 pounds
 Maximum speed with 90 horsepower engine,
 101 m.p.h.

Cruising speed, 85 m.p.h.
 Landing speed, 40 m.p.h.
 Service ceiling, 11,500 feet
 Fuel capacity, 50 gallons
 Gal. per hour, cruising speed, 7 gallons
 Cruising range, 600 miles



FIG. 9.—Eaglerock with OX-5 motor.

Wing span, 36 feet, 8 inches
 Length overall, 24 feet, 11 inches
 Height, 9 feet, 10 inches
 Wing area, 330 square feet
 Weight, empty, 1,459 pounds
 Cockpit load, 340 pounds
 Gross weight, loaded, 2,442 pounds

High speed, 100 m.p.h.
 Cruising speed, 85 m.p.h.
 Service ceiling, 9,000 feet
 Fuel capacity, 46 gallons
 Normal range, 540 miles
 Normal fuel consumption at cruising speed, 7.2 gallons



FIG. 10.—Fairchild No. 71 high-wing monoplane.

Seven passenger, folding wings
 Wing span, 50 feet; wings folded, 14 feet
 Length, land, 33 feet
 seaplane, 37 feet

Wing area, 332 square feet
 Wasp engine, 410 horsepower at 1,900 r.p.m.
 Fuel system, three tanks, 160 gallons

Weight, empty.....
 Disposable load.....
 Gross weight.....
 High speed.....
 Landing speed.....
 Cruising (1,650 r.p.m.).....
 Service ceiling.....
 Initial climb.....
 Climb in 10 minutes.....
 Cruising range (1,650 r.p.m.).....

Landplane
 2,785 pounds
 2,715 pounds
 5,500 pounds
 138 m.p.h.
 55 m.p.h.
 110 m.p.h.
 17,500 feet
 1,050 feet per minute
 7,000 feet
 900 miles

Seaplane
 3,135 pounds
 2,365 pounds
 5,500 pounds
 128 m.p.h.
 55 m.p.h.
 102 m.p.h.
 17,000 feet
 900 feet per minute
 6,500 feet
 850 miles

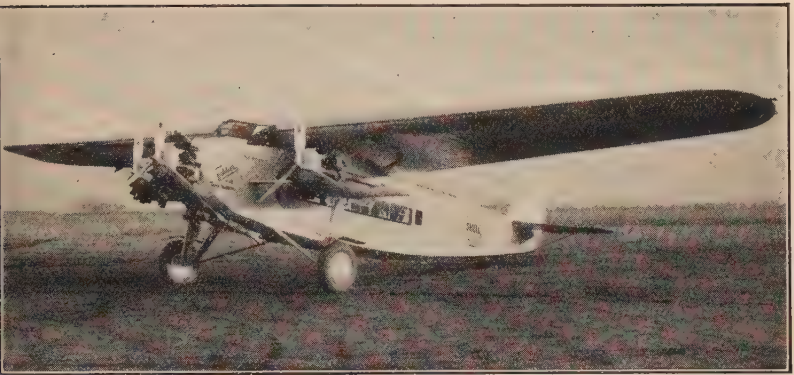


FIG. 11.—Fokker super tri-motor.

Wing span, 79 feet, 3 inches	Oil, 30 gallons; 230 pounds
Length, 50 feet	Crew of two, 340 pounds
Height, 12 feet, 8 inches	Pay load with full tanks, 2,250 pounds
Wing area, 850 square feet	Pay load, $4\frac{1}{2}$ hours range, 3,000 pounds
Weight empty, with standard equipment, 7,500 pounds	Total useful load, 5,000 pounds
Gasoline, 370 gallons; 2,180 pounds	Total plane and load, 12,500 pounds

PERFORMANCE WITH FULL LOAD

	Three Engines	On Two Engines Only
Speed at sea level.....	145 m.p.h.	118 m.p.h.
Cruising speed.....	125 m.p.h.	104 m.p.h.
Landing speed.....	55 m.p.h.	
Climb at sea level.....	1,400 feet per minute	640 feet per minute
Service ceiling.....	18,000 feet	
Range at gasoline consumption of 55 gallons per hour, $6\frac{3}{4}$ hours, 800 miles.		



FIG. 12.—Ford tri-motored transport Model 4-AT.

GENERAL DIMENSIONS

Span, 68 feet, 10 inches
 Length, 49 feet, 0 inches
 Area wings, 740 square feet

Height, 12 feet, 8 inches
 Wheel tread, 15 feet, 4 inches

PERFORMANCE

High speed, 110 m.p.h.
 Cruising speed, 100 m.p.h.
 Stalling speed, 59 m.p.h.

Radius of action (cruising), 500 miles (5 hours)

DATA

Weight empty, 5,200 pounds
 Useful load, 4,000 pounds
 Total weight loaded, 9,200 pounds

Gasoline capacity, 230 gallons
 Wing load per square foot, 12.45 pounds

	Two Engines	Three Engines
Power load (pounds per horsepower).....	23.0 pounds	15.3 pounds

Cabin capacity { Width, 4 feet, 6 inches
 Height, 5 feet
 Length, 15 feet

Passenger accommodation, 335 cubic feet
 (Seats for 12—removable—Baggage hold,
 Toilet, Etc.)



FIG. 13.—The Ireland flying boat.

SPECIFICATIONS

Span upper wing, 40 feet	Propeller, Curtiss-Reed
Span lower wing, 34 feet	Fuel capacity, 65 gallons
Chord, 5 feet, 6 inches	High speed, full load, 110 m.p.h.
Length overall, 30 feet, 6 inches	Cruising speed, full load, 85 m.p.h.
Hull beam at forward step, 5 feet	Landing speed, full load, 46 m.p.h.
Weight empty, 2,250 pounds	Ceiling, 12,000 feet
Pay-load, 750 pounds	Climb at sea level, full load, 650 feet per minute
Useful load, 1,358 pounds	Take-off from water, full load, 25 seconds
Normal gross weight, full load, 3,608 pounds	
Engine, Wright Whirlwind	



FIG. 14.—Keystone pathfinder.

SPECIFICATIONS

Length, 45 feet, 0 inches	Crew, 2
Span, 75 feet, 0 inches	Passengers, 10
Height, 15 feet, 6 inches	Mail and baggage, 300 pounds
Wing Area, 1,140 square feet	Total pay load, 2,460 pounds
Wing Curve, Gottingen 398	Useful load (including 2,025 pounds fuel), 4,485 pounds
Wt. Empty, 6,900 pounds	Range, 750 miles
Wt. Loaded, 11,500–13,500 pounds	

PERFORMANCE DATA

Power plant	3 Wright J-5	3 Pratt and Whitney "Wasp"	3 Wright Cyclone
Total horsepower.....	660	1,275	1,575
R.p.m.....	1,800	1,900	1,920
High speed, m.p.h.....	115	140	150
Landing speed, m.p.h.....	50	54	55
Initial rate of climb, feet per minute.....	600	1,050	1,350
Service ceiling, feet.....	10,000	18,000	20,000
Absolute ceiling, feet.....	12,000	20,000	22,000

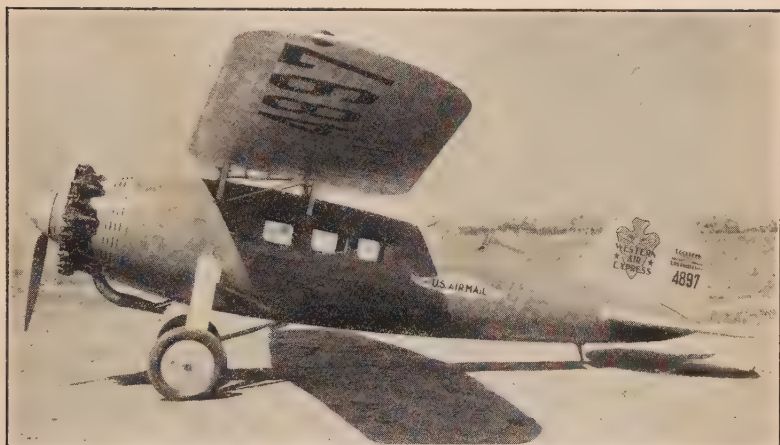


FIG. 15.—Lockheed Wasp—Vega monoplane.

High speed, 170 m.p.h.
 Cruising speed, 135 m.p.h.
 Landing speed, 55 m.p.h.
 Climb at sea level, 1,500 feet per minute
 Service ceiling, 17,250 feet
 Gasoline consumption, at cruising speed
 average, 7 to 8 miles per gallon
 Cruising range, 700 to 800 miles
 Total wing area, 275 square feet
 Wing span, 41 feet
 Length, 27.5 feet
 Weight, empty, 2,050 pounds
 Normal pay load, 1,000 pounds

Seating capacity, five including pilot
 Gross weight, 3,675 pounds
 Gasoline capacity, 100 gallons
 Oil capacity, 10 gallons
 Cabin space, 100 cubic feet
 Baggage compartment, 20 cubic feet
 Fuel system, Gravity from two 50-gallon
 tanks in wing outside of fuselage
 Wing, full cantilever. Plywood covered
 Wing attachment, safety factor of 27
 Control surfaces, plywood covered, operated
 by internal control mechanism



FIG. 16.—Keystone—Loening Amphibian.

Span, overall, 46 feet, 8 inches
 Length, overall, 34 feet, 8½ inches
 Height, overall on wheels, 13 feet, 2 inches
 Chord of wings, 6 feet
 Wing area, including ailerons, 517 square feet
 Airfoil, Loening 10A
 Weight empty, with electric starter, etc., 3,950 pounds

Pay load (with 140 gallon fuel), 1,100 pounds
 Passengers, 6
 Crew, 2
 Disposable load, 1,950 pounds
 Gross weight, 5,900 pounds
 Engine, Wright "Cyclone," 525 horsepower
 Power loading, 11.25 pounds per horsepower
 Wing loading, 11.4 pounds per square foot

PERFORMANCE

High speed, 130 m.p.h.
 Cruising speed, 105 m.p.h.
 Landing speed, 55 m.p.h.

Ceiling, 15,000 feet
 Range at cruising speed (140 gallons), 550 miles



FIG. 17.—Gipsy Moth landplane.

Span—open, 30 feet, 0 inches
Length—overall, 23 feet, 11 inches
Span—folded, 9 feet, 10 inches

Height—overall (tail skid on ground), 8 feet,
9½ inches

85-100 HORSEPOWER DE HAVILLAND GIPSY ENGINE

	At fully loaded weight of 1,350 lbs.	At fully loaded weight of 1,650 lbs.
Full speed at ground level.....	103-105 m.p.h.	102 m.p.h.
Full speed at 5,000 feet.....	100 m.p.h.	97 m.p.h.
Cruising speed at 1,000 ft.....	85-90 m.p.h.	80-85 m.p.h.
Stalling speed.....	40 m.p.h.	44 m.p.h.
Get off and landing		
Length of run to take off.....	80 yards	100-110 yards
Length of run landing.....	100-120 yards	120-130 yards
Height at 500 yards from standstill.....	130 feet	80 feet
Gliding angle.....	1 in 8	
Climb		
Rate of climb at ground level.....	700 ft./min.	500 ft./min.
Time to 5,000 feet.....	9 mins.	13 mins.
Time to 10,000 feet.....	21 mins.	35 mins.
Absolute ceiling.....	18,000 feet	14,500 feet
Range	At a true speed of 80 m.p.h. the range varies from 4½ hours to 5 hours, according to height— giving 360 to 400 miles.	

Performance figures given in Column 1 for total weight of 1,350 lbs. represent machine with pilot and passenger only. Those in Column 2 represent machine loaded up to maximum total weight of 1,650 lbs.

WEIGHTS

Net weight, 900 pounds
Crew at 160 pounds each, 320 pounds
Fuel—19 gallons, 140 pounds

Oil—2 gallon 19 pounds
Luggage (to make up max. total weight), 271 pounds



FIG. 18.—Simplex mid-wing Red Arrow.

Wing span, 34 feet, 3 inches
 Length, 20 feet
 Weight empty, 1,100 pounds
 Useful load, 7,000
 Chord, 60 inches
 Fuel capacity, 54 gallons
 Oil capacity, 5 gallons

Speed, maximum, 125 m.p.h.
 Speed, cruising, 110 m.p.h.
 Speed, landing, 38 m.p.h.
 Take off, 100 to 150 feet
 Climb, 1,000 feet per minute
 Ceiling, 18,000 feet
 Cruising radius, 7 hours

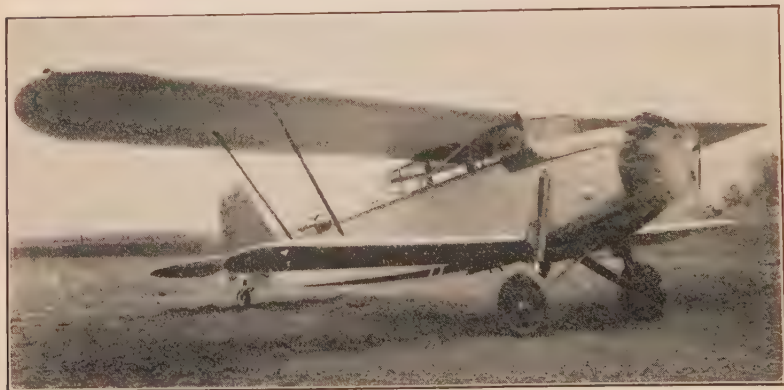


FIG. 19.—Stearman four-place coach.

Wing span, upper, 35 feet
 Wing span, lower, 28 feet
 Total wing area, 297 square feet
 Length, 24 feet
 Height, 9 feet
 Wheel tread, 7 feet, 6 inches
 Cargo space, 30 cubic feet
 Weight, light, 2,565 pounds

Weight loaded, 4,270 pounds
 Fuel capacity, 110 gallons
 Oil capacity, 10 gallons
 Maximum speed, 135 m.p.h.
 Cruising speed, 115 m.p.h.
 Landing speed, 47 m.p.h.
 Service ceiling, 16,000 feet

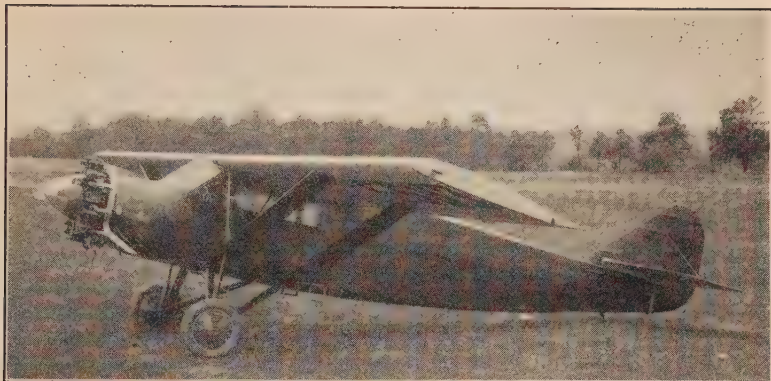


FIG. 20.—Stinson monoplane.

	Stinson tri-motor	Stinson Detroider		Junior 100 h.p.
		300 h.p.	200 h.p.	
Type of plane.....	Monoplane	Monoplane	Monoplane	Monoplane
Number of seats installed.....	14	6	6	4
Power plant.....	3J6 Wright	Wright	Wright	Warner
Length of cabin.....	15 feet, 5 inches	100 inches	100 inches	84 inches
Height of cabin.....	66 inches	51 inches	51 inches	47 inches
Width of cabin.....	46 inches	40 inches	40 inches	37 inches
Wing spread.....	72 feet, 4 inches	45 feet, 10 inches	45 feet, 10 inches	41 feet, 6 inches
Wing area in square feet.....	785	292	292	236
Wing chord.....	13 feet, 9 inches to 8 feet, 4 inches	84 inches	84 inches	75 inches
Length of plane.....	46 feet, 8 inches	32 feet	32 feet	26 feet, 3 inches
Height of plane.....	11 feet, 8 inches	102 inches	102 inches	93 inches
Weight of plane empty, in pounds.....	5,900	2,400	2,400	1,550
Weight with normal load in pounds.....	10,850	4,100	4,300	2,500
Weight with design load in pounds.....	12,500	4,300	4,500	
Useful normal load in pounds.....	4,950	1,700	1,900	950
Normal pay load in pounds.....	2,575	930	1,130	
Cruising speed, miles per hour.....	115	115	105	90
High speed, miles per hour.....	135	135	125	105
Landing speed, miles per hour.....	60	56	56	46
Climb at sea level, per minute.....		1,000 feet	800	600 feet
Service ceiling with maximum load.....		17,000 feet	14,000 feet	13,500 feet
Gliding angle.....	6 to 1	6 to 1	6 to 1	6 to 1
Gasoline capacity.....	300 gallons	90 gallons	90 gallons	45 gallons
Oil capacity.....	30 gallons	6 gallons	6 gallons	4½ gallons
Conservative cruising range.....	700 miles	750 miles	750 miles	500 miles
Fuel consumption hourly, cruising speed.....	45 gallons	15 gallons	12 gallons	7 gallons
Oil consumption per hour, cruising speed.....	1 gallon	1 quart	1 quart	1 quart



FIG. 21.—Travel air, Type 10 four-place, cabin monoplane.

Overall span, 43 feet, 6 inches
 Overall length, 27 feet, 6 inches
 Overall height, 8 feet, 8 inches
 Wing chord, 74 inches

Wing area, 240 square feet
 Wheels, 30 by 5 inches with 32 by 6-inch tires

POWER PLANT

Curtis challenger 170 horsepower or,

Wright, Type R-760, 225 horsepower

CAPACITY

Four occupants and 50 pounds baggage



FIG. 22.—Waco 10.

Wing span, 30 feet, 7 inches
 Length, 23 feet, 6 inches
 Height, 9 feet, 3 inches
 Wing area, 286 square feet
 Total weight, 2,600 pounds
 Pay load, 600 pounds
 Maximum speed with 200 horsepower motor, 135 m.p.h.

Cruising speed, 118 m.p.h.
 Landing speed, 40 m.p.h.
 Service ceiling, 18,000 feet
 Fuel capacity, 65 gallons
 Gallons per hour, 12 gallons
 Seating capacity, 3 persons



FIG. 23. Passenger cabin of Loening amphibian. Pilots are in a separate compartment in front.



FIG. 24.—Passenger cabin of Ford monoplane. Door to pilot's compartment is open.



FIG. 25.—Looking from the pilot's compartment at passenger's cabin of a Boeing transport plane.

that the added safety of the three-motored plane, that can fly on two motors, makes that type more desirable for commercial transport work, especially where passenger carrying is an important item.

To show what is being done in commercial airplanes, in which is included those for personal use, we illustrate a number of planes now being built and give the leading dimensions. Approximately, the same differences and similarities will be noticed as with the same number of automobiles. Cabin fittings and the outside of the planes are following color combinations in much the same way as their counterparts in service on the roads.

Airplanes are following the automobile in body design as to open and closed machines. At present the open-type cockpit prevails in the majority of planes built but there is an increasing number of closed-cabin planes, both for two-passenger planes and for those of large carrying capacity. This is equally true for both land and sea planes.

One great difference, however, is that, in many cases, motors of different makes or horsepower can be used in the same plane. Where a motor is mentioned it represents regular equipment at the time the information was secured, but in most instances almost any make of motor of similar power, or of higher power, can be substituted for the one named.

The interiors of two or three typical large planes will show the tendency at present. The first, Fig. 23, is the Loening amphibian showing the passenger compartment and the door leading to the cabin for the two pilots, or pilot and mechanic. Figure 24 is a large Ford plane for passenger carrying while Fig. 26 is a similar plane built by the Boeing Company. Comparing these with the early Wright machine on page 12 will give some idea of the advances that have been made. Comfortable seats, baggage racks, and individual reading lamps indicate approach to real, commercial transportation.

Air traffic is growing so rapidly that statistics become obsolete with amazing rapidity. Some idea of this growth can be had from the following table on the air-transport mileage of the world up to 1927. The second table is for privately operated mail routes in the United States for the year ending June 30, 1928.

Records, both for speed and endurance, are broken with such regularity that it is useless to cite them here. They are widespread as to nationality. De Pinedo's 60,000-mile Trans-American flight covering almost the entire world except the Pacific ocean, is still a marvel of endurance. The continuous flight of over 6 days without landing, by the Army Fokker, known as the Question Mark, was a triumph of organization, of careful planning, of splendid flying by the pilots of both the Question Mark and of the plane from which it was refueled, both day and night. And this now only notable as being the first long, refuelling flight, as the time in the air has since been nearly trebled. The effect of refuelling in flight on commercial aviation remains to be seen.

TABLE 1.—AIR-TRANSPORT MILEAGE OF THE WORLD¹
(Operations of scheduled services in airplane-miles over 12-month periods as nearly as possible comparable)

Country of registry	Year								
	1919	1920	1921	1922	1923	1924	1925	1926	1927
Australia					235,582	262,895	352,847	417,964	245,043
Austria						160,000	144,500		
Belgium						294,778	446,648 ⁴	631,715 ⁴	
Canada		2,687	53,650	125,678	134,375	169,500	183,206		
Colombia						126,400	48,300		
Czechoslovakia					56,000		114,500	170,895	257,888
Denmark				2,015,000	2,115,000	2,249,000	2,946,000	126,730	116,798
France		505,500	1,460,000	842,986	885,881	1,860,000 ²	3,070,000	3,243,900	3,755,369
Germany							865,000	3,816,144 ⁶	5,921,593
Great Britain	168,000	599,000	259,000	778,000	1,004,000	890,000		840,000	873,000
Italy								96,800	824,474
Mexico		50,850	217,000	246,200	336,000	482,800	679,753	597,500	146,400
Netherlands				66,293	142,057	233,923 ³	465,847		813,510
Poland						288,600	292,595 ⁵		654,873
Soviet Russia						69,280	248,610 ⁵		
Sweden						268,400 ²	87,427		206,766
Switzerland	393,066	880,028	1,828,354	2,329,296	1,743,030	2,220,761		222,000	459,720
United States	561,066	2,038,065	3,818,004	5,903,453	6,651,925	9,576,337	2,910,611	210,340	6,009,226
Totals							12,855,844	15,092,251	20,138,260

³ Revised

⁴ Figures are known to include duplication.

³ Revised

¹ Compiled by Black & Bigelow Inc., New York, N. Y. ² Figure uncertain or known to include duplication.

⁴ Including some non-scheduled flying. ⁵ Incomplete. ⁶ All services suspended for 3 months.

figures.

TABLE 2.—MILEAGE AND TRAFFIC STATISTICS FOR PRIVATELY OPERATED
AIR-MAIL ROUTES WITHIN THE UNITED STATES, FOR YEAR ENDING
JUNE 30, 1928

(Compiled from Post Office Department figures)

Date	Pounds of mail carried	Mail revenue to operator	Airplane- miles flown with mail
July, 1927.....	99,589	\$ 250,891	375,923
August.....	102,051	258,963	376,998
September.....	146,486	312,810	444,519
October.....	153,649	329,532	449,562
November.....	141,992	304,083	413,054
December.....	165,768	353,253	402,267
January, 1928.....	144,289	300,281	431,310
February.....	153,363	329,380	450,058
March.....	173,929	368,191	523,287
April.....	171,028	359,182	513,144
May.....	199,409	425,565	616,179
June.....	210,957	447,642	595,054
Totals for year.....	1,862,510	\$4,039,773	5,591,355
Increase over previous years, per cent.....	265	205	115

SECTION III

RIGGING AND SERVICING THE PLANE

Careful investigation of airplane accidents show that less than 20 per cent can be attributed to mechanical failure of either the engine or plane. The rest are due to failures of the human element in handling the plane or in bad judgment as to weather conditions. Considering the demands made on a plane and its engine the record speaks well for the design, construction, and maintenance of the modern plane. It also imposes a great responsibility on those whose duty it is to keep engines and planes in serviceable condition. Such service work demands a thorough knowledge of the modern plane and a conscientious endeavor to do the most careful and painstaking work. The airplane is no place for a "good enough" job. Every piece of material must be without flaw. Every adjustment must be as near right as it can be made, as failure may mean injury or death to pilot and passengers and hurts aviation.

It is particularly important that no change be made in the adjustment of engines or planes by those who are not thoroughly familiar with them. There have been cases where carbureters have been adjusted to reduce gas consumption until the lean mixture caused overheating of the engine and a forced landing. Such adjustments should be made only by those who are experienced in servicing modern planes. Careful work in servicing engines and planes will reduce the accidents due to mechanical failures, well below to present 20 per cent mark.

With the coming of steel tubing and of other metals into airplane construction, much of the care that was formerly necessary in looking after the woodwork and the connections between the longerons and braces and struts has disappeared. Some woodwork remains in the shape of interplane struts in some cases, although many of these are now of steel with wood fairing, and wing spars or beams are still wood in many cases. Precautions against rust or other deterioration, and cracks and loosening of welded or riveted joints, have replaced

the inspection of wooden parts. Rust-resisting coatings are being used successfully by many builders.

Plane construction is also using more struts in place of wire, but wires still prevail in many constructions and also for controls and other purposes, so that wiring and fittings still play an important part in caring for planes in service. The turnbuckle is still used almost universally for adjusting the tension of any wire to suit the machine to changing conditions. Airplane turnbuckles are specially designed and made with right- and left-hand screw eyes with a connecting nut in the center in the shape of a long barrel. These are of steel, and the threads should be a good fit in the barrel. They should not be very tight nor yet so loose as to make a poor fit and possibly strip the thread



FIG. 1.—Wiring turnbuckle to prevent unscrewing.

under tension. Turnbuckles are all locked in position by a soft locking wire (usually copper or brass), so that the barrel cannot unscrew, even a portion of a turn. This can readily be done by noting which way the barrel must turn to loosen and then twisting the wire through the hole in such a way that it is held against turning in this direction. Figure 1 shows how this can be done.

The rigger must learn to distinguish between the different kinds of wire for different purposes and between the grades which are good and those which are unsuitable for use in various places. The tables in Sec. XI will be found helpful. He should learn the different kinds and sizes of loops and their fastenings, the right and wrong ways of making loops, and the reasons for both. It will be noted that the ferrule is now made of coil wire instead of sheet metal, as was the practice some time ago. These ferrules are wound up over suitable mandrels in long strips and cut off to suit, ten coils being the length advised in most cases. These are more satisfactory in every way, as the sheet-metal ferrule was quite apt to split and release the wire of the loop. There is some difference of opinion as to the advisability of soldering these ferrules, but the tendency is to leave them without solder. This is on account of the necessity of using some kind of acid or soldering

paste and the danger of corrosion from this source. The joints are all covered with some waterproofing compound to prevent the gathering of moisture inside the ferrule.

These loops are necessary whenever a wire is connected to a fitting or to a turn buckle, and this means that a large number are used in every machine. For this reason, it is advisable to become expert in loop making as soon as possible, as this will save much time when it comes to fitting up a machine or to repairing damages. One of the first requirements of a looped connection is that it shall not slip and



FIG. 2.—Beginning the splice.

so change the length of the wire connecting two points, as this affects the tension and may throw one or more parts out of balance.

It takes practice to make good loops in single wires and more practice to splice a cable around a thimble as in Fig. 2. This shows the beginning of a splice, special tools being required to hold the cable around the thimble and to open the strands for weaving in the wires. The clamp used is shown in Fig. 3, the thimble being held and the cable around it being held as shown by the screw at the right. The workman is threading the wires through the opening in the cable where the wires have been spread apart with an awl-pointed tool. A splice of this kind can be made at the bench in about 20 minutes but it requires 30 minutes to do this on the plane.

The best loop, according to American practice, is shown at *A* in Fig. 4. The loops at *B* and *C* are not good as they will change shape under tension. Turn-buckles and all fittings which are concealed by the fuselage and planes should be well protected against rust by special varnish, and are usually wrapped with tape. It is also important to know the qualities of wire, which must not be too hard or too soft. A practical test is as follows:

Take three pieces of wire of the same gage and about a foot long, selecting one which is too soft, one too hard, and the third of the right quality. Clamp in a vise near a window, polishing the wires so as to show light reflections more clearly.

Bend the wire over sharply and as far as possible. The soft wire will flatten out somewhat, as may be told by noting that the band of light on the wire has broadened out at the bend. The hard wire will probably show slight cracks or a roughness of the surface—the beginning of cracks to be developed later. The right wire will show a slightly broader band of light but will not show the slightest roughness of surface. Repeating this

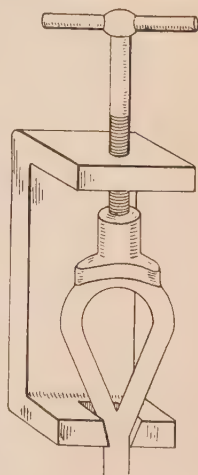


FIG. 3.—Clamp used in Fig. 2.

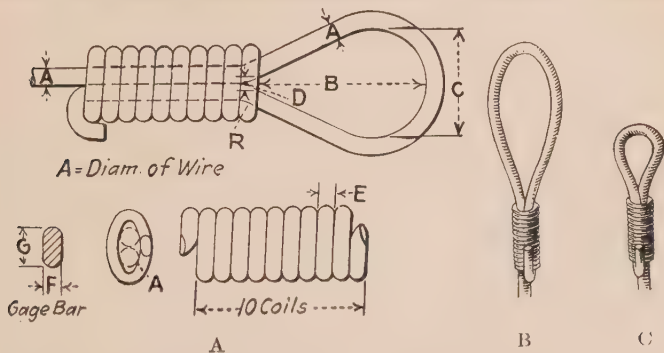


FIG. 4.—Good and bad wire loops.

experiment a few times will show you the good and bad wire and will prove helpful in many ways.

No wire should be used which is damaged in any way. That is to say, it must be *unkinked*, *rustless*, and *unscored*.

All wire must be kept in good condition. Where outside wires are concerned, they should be kept well greased or oiled, especially where bent over at the ends. In the case of internal bracing wires which cannot be reached for the purpose of regreasing them, they should be protected from rusting by painting. The wire must be perfectly clean and dry before painting. A greasy fingermark is sufficient to keep the paint from sticking to the wire.

Tension of Wires.—The tension to which the wires are adjusted is of the greatest importance. All the wires on the airplane should be of the *same tension*. There is a tendency to tension the wires too much. The tension should be *sufficient to keep the framework rigid*. Anything more than that spoils the factor of safety, throws various parts of the framework into undue compression, tends to distort the fittings, and may, in the end, *distort the whole framework* of the airplane. There is, of course, less likelihood of this with the steel frames now in use than with wood.

Only experience can tell what tension to employ and assist in making all the wires of the same tension. Learn the construction of the various types of airplanes, the work the various parts do, and cultivate a touch for tensioning wires by constantly handling them.

Wires with No Opposition Wires.—In some few cases, there are wires having no opposition wire or wires pulling in the opposite direction. In such cases, be *extremely careful* not to tighten such wire beyond taking up the slack.

They must be a little slack, as otherwise they will distort the top spars downward. That will spoil the camber (curvature) of the plane and result in changing both the lift and drift at that part of the plane. Such a condition will cause the machine to lose its directional stability and also to fly one wing down. This matter of tension is of the utmost importance.

Stranded Wire Cables.—No splice should be covered with twine or other wrapping until it has been inspected and passed by whoever is in charge of the work. When a strand becomes broken, the whole cable should be immediately replaced with a new cable. Control cables wear out where they run around pulleys, and any sign of fraying should be attended to at once. The cables should be inspected after

every flight, particularly where they run around the pulleys, and nothing but good cable should be used on the machine.

STRESSES IN WING WIRING

The ordinary set of biplane wings is trussed together by wires in its three dimensions, making it into a pure box girder, but owing to the peculiar functions of an airplane's wings, the different wires employed serve widely different purposes.

It is understood that it is the function of the wings to lift the airplane as a whole. Most of the weight is concentrated in the body, and, therefore, the problem really is how to transmit the lift exerted by the wings to this portion of the airplane.

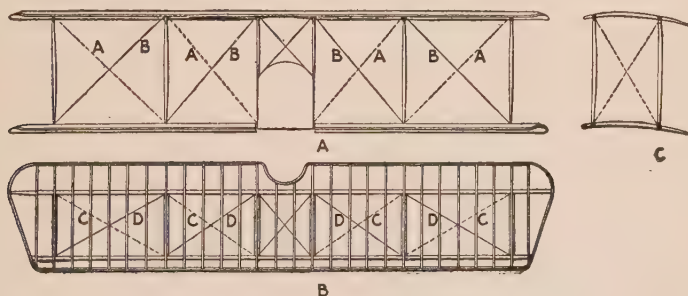


FIG. 5.—Stresses in wiring.

It will be seen from Fig. 5, at A, that when the machine is progressing through the air, the lift exerted on the wings will tend to force them upward, while the weight in the nacelle tends to force them downward at the center. The net result is that the wings try to fold up from the tips inward. The bracing wires prevent this, however. The upward pull of the upper spars puts the lift wire A in tension. The lift on the lower spars puts the interplane struts into compression, the top spars being in compression and the lower spars in tension.

This being the case, there should be no load on the opposing diagonal wires B, when the machine is in the air. They come into play as the machine lands and loses its lift and are therefore known as *landing wires*. With the machine resting on the ground, the whole position is reversed, the landing wires B being in tension and the flying wires A,

slack. The top spars are then in tension and the bottom spars, in compression. The interplane struts remain in compression all the time.

An airplane wing is not merely subjected to the reaction of lift but also to the reaction of drift or resistance. That is to say, the pressure of the air on the machine as it travels through the air reacts in a horizontal sense and tries to fold the wings backward as well as upward. Here the horizontal bracing comes into play, as in Fig. 5, at *B*. The wires *C* (known as *drift wires*) prevent the rear spar from bending backward, and the compression struts hold the front spar at the correct distance. The opposing diagonal wires *D* (known as *antidrift wires*) take the strain when the machine is subjected to a sudden loss of forward speed, as, for example, when landing on rough ground.

The spars are also subjected to a bending moment between each pair of supports, which is at its maximum at the center point between the supports and runs progressively to zero at the actual points of support.

Many airplanes are also fitted with external drift wires running to some point at the front of the machine and external antidrift wires running to the rear.

The third-dimensional bracing serves to hold the upper and lower planes parallel to one another and in correct relation to the rest of the machine (see Fig. 5, at *E*). The change of center of pressure on the wing curve modifies the relative loads placed on each member of these wires, which are known as *incidence wires*.

It should be clearly understood that the stresses imposed on the different wires described are merely those of normal flight. Under peculiar circumstances, both in the air and on the ground, the spars, struts, and wires may be called upon to resist stresses of a much more complicated nature, so that adequate strength must be given to each member.

In order to rig a machine intelligently, it is necessary to have a correct idea of the work every wire and every part of the airplane is doing.

The work the part is doing is known as *stress*. If, owing to undue stress, the material becomes distorted, then such distortion is known as *strain*.

Compression.—The simple stress of *compression* may produce a crushing strain. As an example, the interplane and fuselage struts.

Tension.—The simple stress of *tension* results in the strain of elongation. As an example, all the wires are subjected to elongation.

Bending.—The compound stress of *bending* is composed of both tension and compression; one side is stretched, the other compressed.

Shear.—Shear stress is such that when the material breaks under it, one part slides over the other. As an example, the locking pins. Some of the bolts are in a state of shear stress, also, because, in some cases, there are lugs underneath the boltheads from which wires are taken. Owing to the tension of the wire, the lug is exerting a sideways pull on the bolt and trying to break it in such a way as to make one part of it slide over the other.

Torsion.—This is a twisting stress composed of compression, tension, and shear stress. The propeller shaft and crankshaft of the engine are good examples.

Nature of Wood under Stress.—Wood, for its weight, stands the stress of compression well. A walking stick of about half a pound in weight, will, *if* kept perfectly straight, probably stand up to a compression stress of a ton or more before crushing, whereas, if the same stick is put under a bending load, it will collapse under a stress of not more than about 50 pounds. Wood must, as far as possible, be kept in a state of *direct compression*. This it will do safely as long as the following conditions are carefully observed:

Conditions to Be Observed.—1. All the spars and struts must be *perfectly straight*.

Figure 6 shows a section through an interplane strut. If it is to be prevented from bending, the stress of compression must be equally disposed around the center of strength. If it is not straight, there will be more compression on one side of the center of strength than on the other side. That is a step toward getting compression on one side and tension on the other side, in which case it will be forced to take a bending stress for which it is not designed.

Even if it does not break, it will, in effect, become shorter and thus throw out of adjustment all the wires attached to the top and bottom of it, with the result that the flight efficiency of the airplane will be spoiled, and an undue and dangerous stress thrown upon other wires, as in Fig. 7.

2. Struts and spars must be *symmetrical*. By that is meant that the cross-sectional dimensions must be correct, as otherwise there will

be bulging places on the outside, with the result that the stress will not be evenly disposed around the center of strength, and a bending stress will be produced.

3. Struts, spars, etc., must be *undamaged*. Remember that, from what has been said about bending stresses, the outside fibers of the

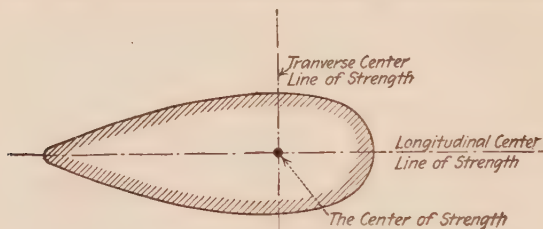


FIG. 6.—Section of strut.

wood are doing by far the most work. If these get bruised or scored, then the strut or spar suffers in strength much more than one might think at first sight, and if it ever gets a tendency to bend, it is likely to go at that point.

4. The wood must have a *good clear grain with no cross-grain, knots, or shakes*. Such blemishes mean that the wood is in some places

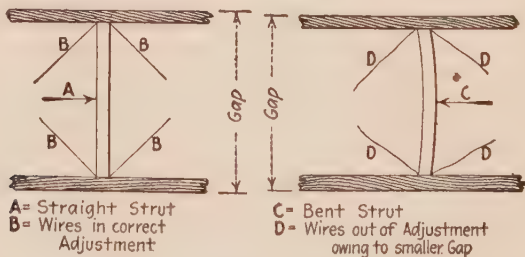


FIG. 7.—Effect of bent struts.

weaker than in other places, and, if it has a tendency to bend, then it will go at those weak points.

5. The struts, spars, etc. must be *properly bedded* into their sockets or fittings. To begin with, they must be a good pushing or gentle tapping fit. They must never be driven with a heavy hammer. Then, again, they must bed down well, all over their cross-sectional area; otherwise the stress of compression will be taken on one part of

the cross-sectional area with the result that it will not be evenly disposed around the center of strength, and that will produce a bending stress. The bottom of the strut or spar should be covered with some sort of paint, bedded into the socket or fitting and then withdrawn to see if the paint has stuck all over the bottom of the fitting.

6. The atmosphere is sometimes much damper than at other times, and this causes the wood to expand and contract appreciably. This would not matter but for the fact that it does not expand and contract uniformly but becomes unsymmetrical, *i.e.*, *distorted*. This should be minimized by varnishing the wood well to keep the moisture out of it.

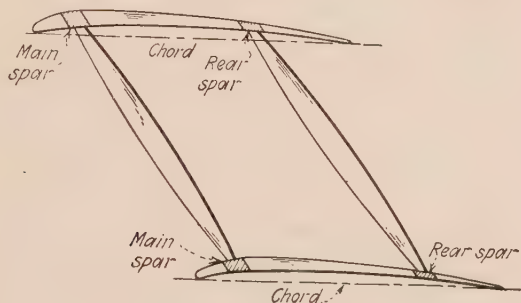


FIG. 8.—Length of struts.

Function of Interplane Struts.—These struts have to keep the planes apart, but this is only part of their work. They must also keep the planes in their *correct attitude*. That is only so when the spars of the bottom plane are parallel with those of the top plane. The chord of the top plane must also be parallel with the chord of the bottom plane. If that is not so, then one plane will not have the same angle of incidence as the other one.

It would seem necessary only to cut all struts the same length, but that is not the case. Sometimes, as illustrated in Fig. 8, the rear spar is not so thick as the main spar, and it is then necessary to make up for that lack of thickness by making the rear struts correspondingly longer. If that is not done, then the top and bottom chords will not be parallel, and the top and bottom planes will have different angles of incidence. Also, the sockets or fittings or even the spars upon which they are placed sometimes vary in thickness, and this must be offset by altering the length of the struts. The proper way to proceed in order

to make sure that everything is right is to measure the distance between the top and bottom spars by the side of each strut, and, if that distance, or *gap*, as it is called, is not as specified in the rigging diagram, make it correct by changing the length of the strut. When measuring the gap between the top and bottom spars *always be careful* to measure from the *center* of the spar, as it may be set at an angle, and the rear of the spar may be considerably lower than its front.

The measuring of the dihedral angle of wings can be done in two or more ways, the first or string method being the more satisfactory. A cord or fine wire is stretched over the top of the wing, as in Fig. 9, and

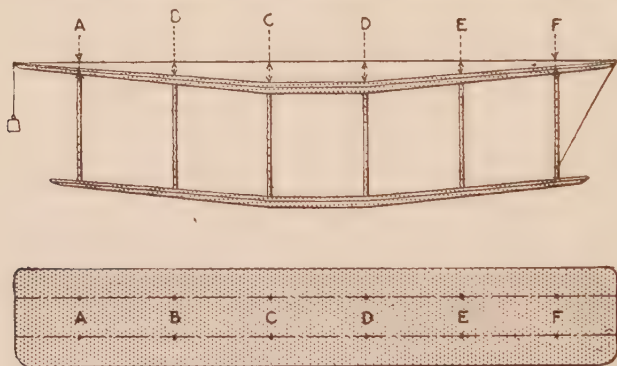


FIG. 9.—Measuring dihedral angle. •

held in several ways. A tripod may be used at one end and a weight at the other to keep it taut, or one end may be tied over the edge to a strut, or both ends may be secured in this way. Then, with the cord bearing on top of the wing at each end, measure the distance between the chord and the plane at definite points, taking equal points each side of the center panel of the machine. This should be done at both the front and back edges of the plane or, more properly, over the two main spars of the wing. This is done just as much to measure the angle of incidence as to check up the two sides of the machine and see that the angles are alike. By keeping notes of these measurements the rigger can easily detect any change which may occur.

Two strings should be used, one over each spar, and drawn very tight. The points measured should be just inside the four center-section struts, in other words, as far as possible from the center of the center section.

Diagonal measurements are also taken, from similar points on each side of the machine. These measurements should be taken from fixed points, such as certain distances from the ends of the spars. Many take these measurements from the bottom socket of one strut to the top socket of another strut, but this is not good practice, as it seldom gives

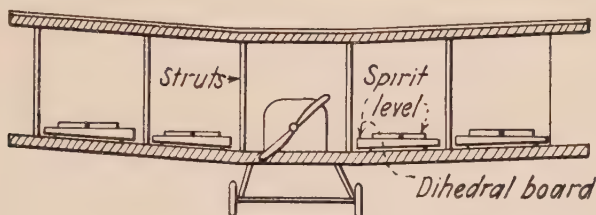


FIG. 10.—Use of dihedral board.

accurate measurements. By measuring the distance between top and bottom planes it can readily be seen whether they are both set at the same angle.

Another method and one which is easier to use, although not usually accurate, is by the use of the dihedral board, as shown in Fig. 10. This is simply a board cut with the proper angle for the dihedral on one side. These boards should be tested before using, and care must be taken that the spar is not warped or "set" at the points where they are used. For, as these must be used on the spars between the struts, slight inaccuracies often creep in from this source. The bays or sections between struts must be carefully measured diagonally as a check to the use of the boards. This same type of board is used to measure angle of incidence, as shown in Fig. 11, but the level goes on the long, straight board. In all cases, be sure the level is accurate.

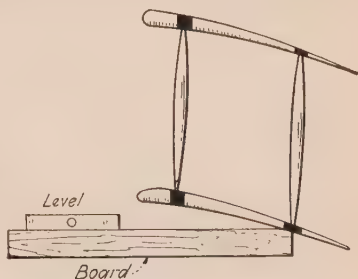


FIG. 11.—Measuring angle of incidence.

MEASURING THE STAGGER

The amount of stagger is measured by dropping a plumb line from the leading edge of the upper plane and measuring back, as shown

in Fig. 12. This can be measured either horizontally or along the line of the chord. Some makers measure one way and some another, but the correct way should be shown on the diagram which should accompany every plane. This is the only way in which a rigger can check up his work as he goes along. The two measurements may have as much as a quarter of an inch difference, and while this may seem but a trifle, it may be enough to make the machine nose heavy or tail heavy, as the case may be.

If any adjustments are found necessary, and they usually are, they should be very carefully made, taking great care not to spring any of

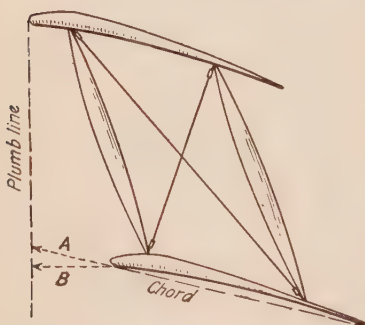


FIG. 12.—Measuring the stagger of planes.

the important parts, such as the wing spars. It is also well to run over all adjustments after the last one is made to be sure that this has not thrown some of the others out of place.

After all other measurements have been taken and adjustments made, the overall measurements will tell whether the machine as a whole is in good shape or not. These are taken as in Fig. 13. The points A and B are marked on the main spar, each the same distance from the butt or end next the fuselage. In

a tractor machine, the point C is the center of the propeller shaft; in a pusher, the center of the front end of the machine. From A to C and from B to C must, of course, be the same, these measurements being taken from both the top and bottom wing of the machine, making two measurements on each side of the machine.

In the same way, mark two points D and E on the rear spars of each wing and measure back to a point F in the center of the fuselage or rudder post. Here, again, two measurements are necessary on each side.

Should these measurements not check up as they should, it is possibly because some of the resistance or drift wires are not tightened evenly, or the fuselage may possibly be out of true. This should, however, have been tested before the rest of the measurements were taken. The fault must be found and corrected before the machine is in condition to fly.

A little study of Fig. 14 will enable the rigger to keep in mind some of the main points of the machine. It will be seen that the center of

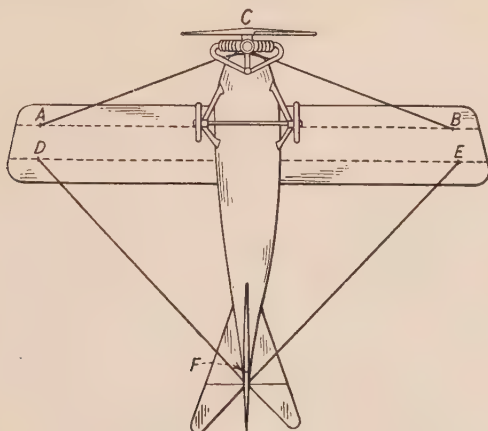


FIG. 13.—Measuring trueness of whole machine.

resistance, or drift, is above the center of thrust, or the center of the engine shaft, and parallel to it. The center of gravity is a little for-

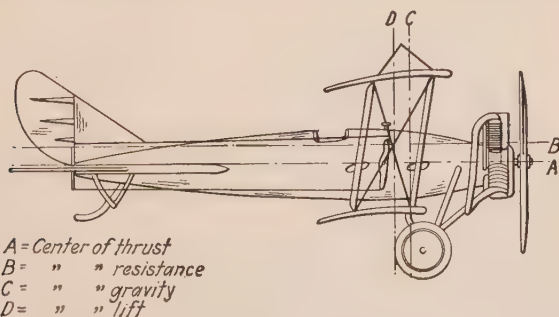


FIG. 14.—Location of thrust, resistance, gravity and lift.

ward of the center of lift so that, with the power shut off, the machine will naturally assume its proper gliding angle, which should give the same speed as when flying.

As the air comes through the main planes it is deflected downward, as shown in Fig. 15. This affects the angle of the tail plane, which may either be in line with this downward stream of air or at a lesser angle than the main wings. This stream of air affects the fore and aft stability of the machine.

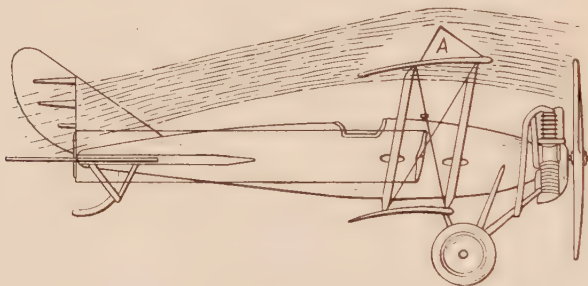


FIG. 15.—How air stream affects the tail surfaces.

THE STABILITY OF AIRPLANES

Stability.—By the stability of the airplane is meant the tendency of the airplane to remain upon an even keel and to keep its course; that is to say, not to fly one wing down, tail down, or nose down, or to try to turn off its course.

Directional Stability.—By directional stability is meant the natural tendency of the airplane to remain upon its course. If this did not exist it would be continually trying to turn to the right or to the left, and the pilot would not be able to control it.

For the airplane to have directional stability, it is necessary for it to have, in effect, more keel surface behind its turning axis than there is in front of it.

By keel surface is meant everything you can see when you look at the airplane from the side of it—the sides of the body, undercarriage, wires, struts, etc. Directional stability is sometimes known as “weather-cock” stability.

You know what would happen if, in the case of the weathercock, there was too much keel surface in front of its turning axis, which is the point upon which it is pivoted. It would turn around the wrong way. That is just how it is with an airplane.

Directional stability will be badly affected if there is more drift (*i.e.*, resistance) on one side of the airplane than there is on the other side. This may be caused as follows:

1. The angle of incidence of the main planes or the tail plane may be wrong. If the angle of incidence on one side of the machine is not what it should be, that will cause a difference in the drift between the two sides of the airplane, with the result that it will turn off its course.
2. In the alignment of the fuselage, the fin in front of the rudder

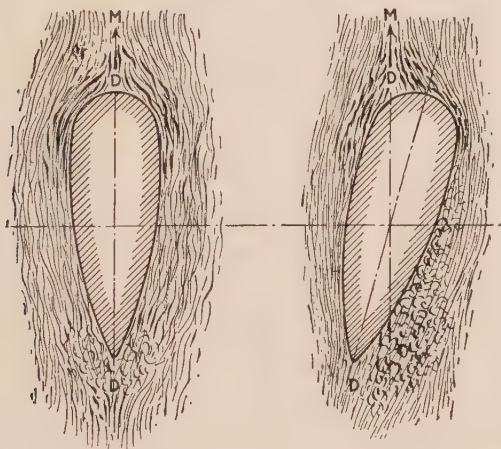


FIG. 16.—Air currents around struts.

must be absolutely correct. For, if it is turned a little to the left or to the right, instead of being in line with the center of the machine and dead on in the direction of flight, it will act as an enormous rudder and cause the machine to turn off its course.

3. If the dihedral angle is wrong, that may have a bad effect. It may result in the propeller not thrusting from the center of the resistance, in which case it will pull the machine a little sideways and out of its course.

4. If the struts and stream-line wires are not adjusted to be dead on in the line of flight, then they will produce additional drift on their side of the airplane, with the result that it will turn off its course.

5. There is still one other reason why the airplane may be directionally bad, and that is *distorted surfaces*. The planes are "cambered," or curved, to go through the air with the least possible resistance. If, perhaps, owing to the leading edge, spars, or trailing edge becoming bent, the curvature is spoiled, that will change the amount of drift on one side of the airplane which will then have a tendency to turn off its course (see the struts in Fig 16).

Lateral Stability.—By lateral stability is meant the sideways balance of the machine. The only possible thing that can make the machine fly one wing down is that there is more lift on one side than on the other. That may be due to the following reasons:

1. *The Angle of Incidence May Be Wrong.*—If the angle of incidence is too great, then it will produce more lift than on the other side of the machine, and if the angle of incidence is too small, then it will produce less lift than on the other side, the result being that in either case the machine will try to fly one wing down.

2. *Distorted Surfaces.*—If the planes are distorted, then their camber or curvature is spoiled and the lift will not be the same on both sides of the airplane, and that, of course, will cause it to fly one wing down.

Longitudinal Stability.—Longitudinal stability means the fore and aft balance. If that is not perfectly right then the machine will try to fly nose down or tail down. This may be due to the following reasons:

1. *The Stagger May be Wrong.*—The top plane may have drifted back a little, and this will probably be due to some of the wires having elongated their loops or having pulled the fittings into the wood. If the top plane is not staggered forward to the correct degree, then that means that the whole of its lift is moved backward and it will then have a tendency to lift up the tail of the machine too much. In such a case, the machine would be said to be "nose heavy."

A $\frac{1}{4}$ -inch error in the stagger may make a very considerable difference to the longitudinal stability.

2. Incorrect angle of incidence of the main planes will have a bad effect. If the angle is too great, it will produce an excess of lift, which will lift up the nose of the machine, causing it to fly tail down. If the angle is too small, there will be a decreased lift, and the machine will try to fly nose down.

3. When the machine is longitudinally out of balance, the usual thing is for the rigger to rush to the tail plane, thinking that its adjust-

ment relative to the fuselage must be wrong. This is, indeed, sometimes the case, but it is the least likely reason. It is much more likely to be one of the first two reasons given, or the following:

The fuselage may have warped upward or downward, thus giving the tail plane an incorrect angle of incidence. If the tail plane has too much angle of incidence, it will make it lift too much, and the machine will be nose heavy.

If the tail plane has too little angle of incidence, then it will not lift enough, and the machine will be "tail heavy." Many modern planes have a tail plane or stabilizer, that can be adjusted to different angles of incidence. Some can be adjusted in flight.

4. If the above three points are all correct, then there is a possibility of the tail plane itself having assumed a wrong angle of incidence, in which case it must be corrected. In such event, if the machine is nose heavy, the tail plane should be given a smaller angle of incidence. If the machine is tail heavy, then the tail plane must be given a larger angle of incidence, *but* be careful not to give the tail plane too great an angle of incidence, because the longitudinal stability of the airplane entirely depends on the tail plane being set at a *much smaller angle of incidence* than the main plane, and if you cut the difference down too much the machine will become uncontrollable longitudinally.

ADJUSTMENTS AND INSPECTION

Control Surfaces.—The greatest care must be exercised in properly rigging the aileron, rudder, and elevator, for the pilot entirely depends upon them in managing the airplane.

The ailerons and elevator should be rigged so that *when the machine is in flight* they are in a fair line with the surface in front and to which they are hinged, as in Fig.17.

If the surface to which they are hinged is *not a lifting surface*, then *rig* the controlling surface to be in a fair, true line with the surface in front.

If the controlling surface is hinged to the back of a *lifting surface*, then it is necessary for it to be rigged a little below what it would be if it were in a fair true line with the surface in front. This is because, in such a case, it is set at an angle of incidence. This angle will, when the machine is flying, produce lift and cause it to lift a little above

the point at which it has been rigged on the ground. It is able to lift owing to a certain amount of slack in the control wire holding it, and the control wire can not be adjusted to have no slack, because that would cause it to bind against the pulleys and make the operation of it too hard for the pilot. It is, therefore, necessary to rig it a little below what it would be if it were rigged in a fair, true line with the surface in front. Remember that this applies only when it is hinged to a lifting surface. The greater the angle of incidence of the lifting surface in front the more the controlling surface will have to be rigged down. As a general rule, it can be safely rigged down so that the trailing edge of the controlling surface is $\frac{1}{2}$ to $\frac{3}{4}$ inch below where it would be if it were in a fair, true line with the surface front, or $\frac{1}{2}$ inch down for every 18 inches of chord of the controlling surface.

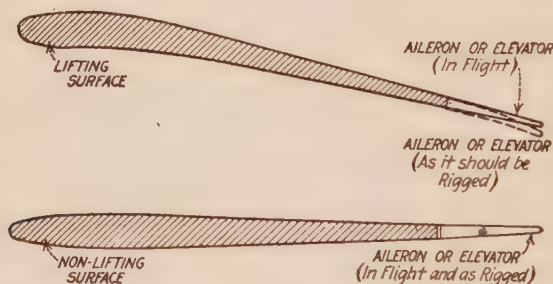


FIG. 17.—Rigging ailerons.

When adjusting the controlling surfaces, the pilot's control levers must be in their neutral position. It is not sufficient to lash them in that position. They should be blocked into position with wood packing.

Remember that controlling surfaces must never be adjusted with a view to altering the stability of the machine. Nothing can be accomplished in that way. The only result will be that the control of the airplane will be spoiled.

Control Cables.—The adjustment of the control cables is quite an art, and upon it will depend to a large degree the quick and easy control of the airplane by the pilot. The method is as follows:

After having rigged the controlling surfaces, remove the packing which has kept the control levers rigid. Then, sitting in the pilots' seat, move the control levers *smartly*.

Tension up the control cables so that when the levers are smartly moved there is no perceptible snatch or lag. Be careful not to tension up the cables more than necessary to take out the snatch. If you tension them too much, the cables will bind round the pulleys and result in hard work for the pilot and also in throwing dangerous stresses upon the controlling surfaces, which are sometimes of rather flimsy construction. It will also cause the cables to fray round the pulleys more quickly than would otherwise be the case.

Now, after having tensioned the cables sufficiently to take out the snatch or lag, place the levers in their neutral position and move them backward and forward not more than $\frac{1}{8}$ inch either side of the neutral position. If the adjustment is correct, you should be able to see the controlling surfaces move. If they do not move, then the cables are too slack.

Flying Position.—Before rigging the machine, it is necessary to place it in what is known as its "flying position."

This is best secured by packing up the machine so that the engine foundations are perfectly horizontal both *longitudinally* and *laterally*.

This is done by placing a straight-edge and a spirit level on the engine foundations, and you must be very careful indeed to see that the bubble is exactly in the center of the level. The slightest error will be much magnified toward the wing tips and tail. Great care should be taken to block the machine up *rigidly*. In case it gets accidentally disturbed during the rigging of the machine, you should constantly verify the flying position by running the straight-edge and the spirit level over the engine foundations. *Carefully test the straight-edge for truth before using it*, for, being usually made of wood, it will not remain true long. Place it lightly in a vise and in such a position that a spirit level on top shows the bubble exactly in the center. Now slowly move the level along the straight-edge. The bubble should remain exactly in the center. If it does not, then the straight-edge is not true and must be corrected. *Never omit doing this.*

With radial engines the bolt bosses on the mounting ring can be tested for vertical squareness by a level that rests on upper and lower bosses. Lateral squareness must be tested from the center line of the plane.

Propellers.—The last thing to go onto the machine is, as a rule, the propeller, by which time there is usually a rush to get the machine out.

Be very careful, however, to see that the propeller is fitted on true and straight. This is easily verified by bringing the tip of one blade round to graze some fixed object, such as a trestle. Mark the place where the tip of the blade touches it. Now bring the tip of the other blade round and it should be within $\frac{1}{8}$ inch of the mark. If it is not so, then it is probably due to some of the propeller bolts being pulled up too tight. It may be due to the propeller itself not being true (See notes on propellers).

Fuselage.—The methods of truing fuselages are laid down in the rigging diagrams. After having adjusted the fuselage according to the specified directions, arrange it on trestles in such a way as to make about three-quarters of the fuselage toward the tail stick out unsupported. In this way, you will get as near as possible to flying conditions, and, when it is in this position, the adjustments should be run over again. If this is not done, the fuselage may be out of true but perhaps appear all right when supported by trestles at both ends, as, in such cases, its weight may keep it true as long as it is resting upon the trestles.

Tail Plane.—The exact angle of incidence of the tail plane is given in the rigging diagram. Be careful to see, however, that the spars are horizontal. If they are tapered spars, then see that their center lines are horizontal. After the tail plane has been rigged, support the machine so that the tail is unsupported, as explained above. Then verify the adjustment and make sure that the tail-plane spars are horizontal when the machine is in flying position. Tail planes are also called stabilizers.

Rudder, Ailerons, Elevator.—These controlling surfaces must not be distorted in any way. If they are held true by bracing wires, then such wires must be carefully adjusted. If they are distorted and there are no bracing wires with which to true them up, then the matter should be reported, as it may be necessary to replace some of the internal framework.

Undercarriage.—The undercarriage must be carefully aligned, as laid down in the rigging diagram.

1. Be very careful to see that the undercarriage struts bed well down into their sockets. If this is not done, then, after having had a few rough landings, they will bed down farther and throw the undercarriage out of alignment, with the result that the machine will not taxi straight.

2. When the undercarriage is being rigged, the airplane must be packed up in its flying position and sufficiently high so that the wheels are off the ground. When in this position, the axle must be horizontal.

3. Be very careful to see that the shock absorbers are of equal tension and that the same length of elastic and the same number of turns are used in the case of each absorber. If hydraulic or similar shock absorbers are used, see that they are in good condition. See Sec. VII for details.

Handling of Airplanes.—An extraordinary amount of damage is done by the mishandling of airplanes and in packing them up from the ground in the wrong way. The golden rule to observe is:

PRODUCE NO BENDING STRESSES

1. The wood used in the airplane is designed to take stress of direct *compression* and it cannot be safely bent. Care should also be taken with all metal construction not to bend the tubes or other members. In packing an airplane up from the ground, the packing must be used in such a way as to come underneath the interplane struts and the fuselage struts. Soft packing should always be placed on the points upon which the airplane rests.

2. When pulling the machine along the ground, always, if possible, pull from the undercarriage. If necessary to pull from elsewhere, then do so by grasping the interplane struts as low down as possible.

3. As regards handling parts of airplanes, never lay anything covered with fabric on a concrete floor, as any slight movement will cause the fabric to scrape over the concrete with resultant damage.

4. Struts, spars, etc. should never be left about the floor, as in such a position they are likely to become damaged. Remember, also, that wood easily becomes distorted. This particularly applies to the interplane struts. The best method is to stand them up in as near a vertical position as possible.

KEEPING THE AIRPLANE IN GOOD CONDITION

Cleanliness.—The fabric must be kept clean and free from oil, as dirt and oil will rot it.

To take out dirt or oily patches, try acetone. If that will not do the job, try gasoline but use it sparingly or it will take off an unnecessary amount of dope. If that will not remove it, then hot water and soap

will do so, but, in that case, be sure to use soap having no alkali in it, as otherwise it will badly affect the fabric. Use the water sparingly; otherwise it may get inside the planes and rust the internal bracing wires or cause some of the wooden framework to swell.

The wheels of the undercarriage have a way of throwing up a great deal of mud on the lower plane. This should be taken off at once. Do not allow it to dry and do not try to scrape it off when dry. If dry, then it must be moistened first, as otherwise the fabric will be spoiled.

Controlling Wires.—After every flight, pass your hand over the control wires and carefully examine them near pulleys.

If even one strand is broken, the wire must be changed. Do not forget the aileron balance wire on the top plane.

Once a day try the tension of the control wires by smartly moving the control levers about, as explained primarily.

Wires.—See that all wires are kept well greased or oiled and that they are all in the same tension. When examining your wires, be sure to have the machine on level ground, as otherwise it may get twisted, throwing some wires into undue tension and slackening others. The best way, if you have time, is to pack the machine up into its flying position.

If you see a slack wire, do not jump to the conclusion that it must be tensioned. Perhaps its opposition wire is too tight, in which case, slacken it, and possibly the slack wire will thus be tightened.

Carefully examine all wires and their connections near the propeller and be sure that they are snaked round with safety wire, so that the latter may keep them out of the way of the propeller, if they come adrift.

Distortion.—Carefully examine all surfaces, including the controlling surfaces, to see whether any distortion has occurred. If distortion can be corrected by the adjustment of wire, well and good, but if not, then report the matter.

Adjustment.—Verify the angle of incidence, the dihedral angle, the stagger, and the overall measurements as often as possible.

Undercarriage.—Constantly examine the alignment and fittings of the undercarriage and the condition of tires, shock absorbers, and tail skid.

Control Surfaces.—As often as possible verify the rigging position of the ailerons and elevator.

Locking Arrangements.—Constantly inspect the locking arrangements of all turnbuckles, bolts, etc.

Outside Position.—The airplane, when outside its shed, must always stand *facing the wind*. If this is not so, then the wind may catch the controlling surfaces and move them sharply enough to damage them. If the airplane must be moved during windy weather, then the control levers should be lashed fast.

RIGGING A STEARMAN C-3B BIPLANE

Tram the center-section cross-brace wires by equalizing the diagonal measurements between the bolthead centers of the upper and lower center-section strut bolts. These boltheads are center punched so that the measurements can be accurately and conveniently made.

Next measure the distance between the center of the upper diagonal center-section strut bolt and the center of the bolthead of the adjustable clevis pin on the same strut. This distance should be $36\frac{1}{16}$ inches. The adjustment at the lower end of this diagonal strut should continue until the correct measurement is obtained.

After this operation has been completed and carefully checked the lower wings may be placed in position and held in place by the front landing wires. These wires are attached to an improvised hook on the top of the front center-section strut.

The upper wings should then be placed in position, care being taken that the ailerons and aileron-torque tubes are in place.

Attach the outer bay-wing struts and fasten them in position.

The upper wings should now be pulled into position by aligning the entering edges so that they are in a straight line with the entering edge of the center section. This is done by tightening and loosening the front landing wires until the proper alignment is secured.

Now tighten the front landing wires five turns to give the proper dihedral angle. The rear landing wires should then be pulled to the same tension.

Tighten the front flying wires snugly at this point and then adjust the outer bay diagonal struts to eliminate all "wash in" and "wash out."

The rear flying wires should then be drawn up so that they fit snugly. All flying wires should be taut but not strained to any undue tension.

If these instructions are carefully followed, the rigging is complete

and the plane will have the proper dihedral angle and stagger. The plane will also have the proper angle of incidence and no "wash in" or "wash out."

SETTING UP THE WACO-10 BIPLANE

It is suggested that bolts and pins be cottered as they are inserted, to prevent overlooking this important point. The left-hand thread on all stream-line wires should go at the top.

Assembling the Landing Gear.—Hold the Oleo-strut in vertical position with the top up as in Fig. 18. Pull piston out of cylinder and fill cylinder with General Electric Transformer oil No. 6. No substitute for this oil can be recommended but if impossible to procure it, a light motor oil having a *low cold test* can be used.

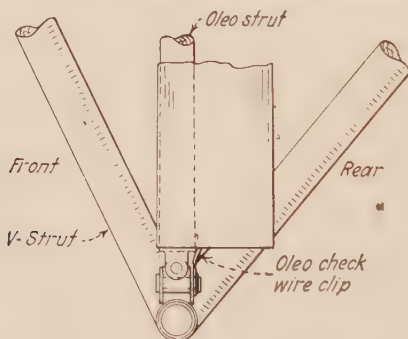


FIG. 18.—View of Oleo Strut connected to V Strut.

Place piston back in cylinder and push to bottom. Remove piston and add oil until its level is 6 inches from the top. Do not attempt to put the piston from one cylinder into another as they are not interchangeable. Keep piston and cylinder together as shipped. With piston again inserted in cylinder the strut is ready to be mounted on the landing gear (for full assembly details see Fig. 27). Put wheels on landing-gear V's with three axle washers inside. Limit end play of wheel on axle by putting enough washers between wheel and hub cap. Put hub cap in place and bolt securely, locking with cotter.

Motor end of fuselage must be raised with hoist to install landing gear. Put bushings in upper ends of landing-gear V's. Spread plate

fitting on fuselage slightly to admit V ends with bushings in place. Bolt landing-gear V's in place (see Fig. 19). Fasten top of Oleo-strut to fuselage, removing cowl piece under this point, if necessary, to insert bolt. Fasten bottom of Oleo-struts to V's (Fig. 19). The clip on the lower end of check wire inside stream-line cover of Oleo strut should be fastened to the rear of bottom Oleo connection to V's, using the $\frac{3}{8}$ -inch bolt.

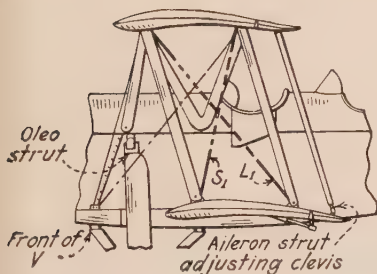


FIG. 19.—Landing gear connections.

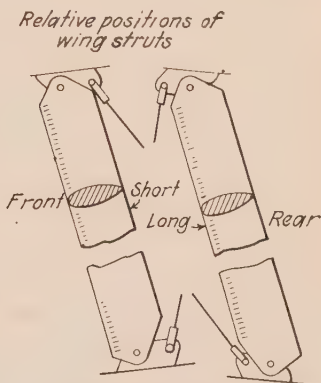


FIG. 20.—Fastening interplane struts.

Wing Rigging.—Remove all stream-line wire ends and screw them back five complete turns to insure an equal amount of adjustment on each thread end. Fasten interplane struts on upper wings as indicated by Fig. 20. Cut inspection hole on underside of fuselage. This will give a rectangular opening inside the line of tacks provided for the purpose. Cut out the cloth inside the patches on both sides of the inspection hole for aileron control rods. Cut slot in small adjacent patches for lower wing tie wire. Front wing root fittings for lower wing should be bolted to fuselage and the rear fittings bolted to the wing. The wires are marked with brass sleeve tags.

Hang landing wires on the center-section fittings but do not tighten (see Fig. 21). Place lower wing between fittings on fuselage, drive long $\frac{5}{16}$ -inch bolts through front wing root fitting and front spar. Fasten the landing wires to wing fittings (Figs. 22 and 23). After both wings are hung, fasten rear wing root fittings to the fuselage.

Place root end of upper wings with interplane struts attached as before mentioned, between fittings on center section. Line up entering edge of wings with entering edge of center section. Line up holes in spars. Drive long $\frac{5}{16}$ -inch bolts in front spars first, following with bolts in rear spars. Fasten interplane struts on the lower wing.

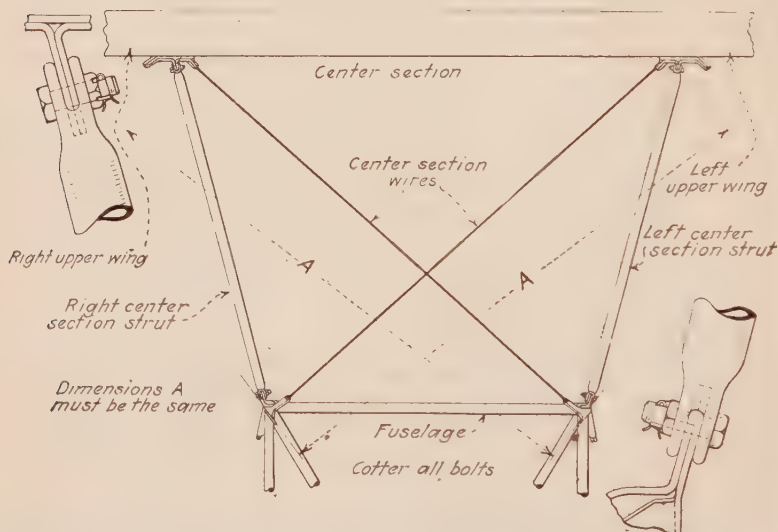


FIG. 21.—Diagram of center section struts and landing wires; looking from front.

Now tighten center-section wires. These must be adjusted until the length of center-section wires as *A*, Fig. 21, are the same on each side. This can best be done by measuring with trammels. Put a safety wire on each turnbuckle when wires are correctly adjusted.

Fasten both ends of flying wires but do not tighten.

Draw up front landing wires until they are 8 feet 2 inches from center to center of pins. Tighten rear right landing wires, *RL* (Fig. 22), so that front and rear spars are parallel when sighted from the front of the plane along the chord on the underside of wing. The left rear-landing wire should be about $\frac{1}{4}$ inch longer than the right landing wire. This permits the rear spar on this side to droop slightly which takes care of the torque, or turning effect of the motor.

Tighten front flying wires, *FF*, and drift flying wires *DF* both Fig. 22, to a length approximately as noted, and readjust them until the leading edge of the upper wings is parallel with the leading edge of the lower

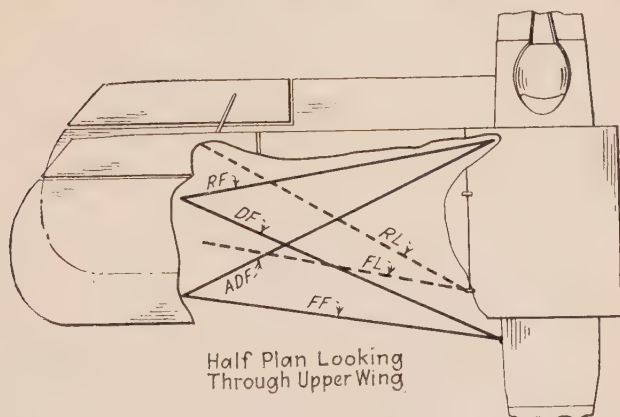


FIG. 22.—Set-up diagram for wing wires and struts.

wings. This is usually done by lying on your back under the lower wing and sighting along both edges.

Tighten the rear flying wires, *RF*, and the antidrift wires, *ADF*, Fig. 22 until they are snug. Tighten the incidence wires *S*₁ and *L*₁.

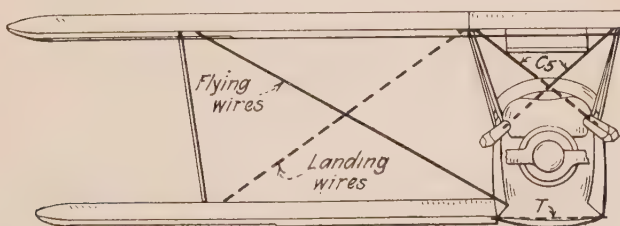


FIG. 23.—Position of flying and landing wires.

Fig. 19, snug, bringing the tension on both wires at the same time. Tighten locknuts on all stream-line wires. Push the bottom wing tie wire (this is a short stranded wire) through the slot in the fuselage

cover and fasten both ends with clevis pins. Tighten snug and wire for safety. (See flying and landing wires in Fig. 23.)

Aileron Control.—Put the control stick in the center, and have bottom ailerons in line with wings. Adjust short aileron rods (the rods used to connect the stick lever to the rods in the lower wings) to the right length to keep the stick and ailerons in their proper relationship. Tighten

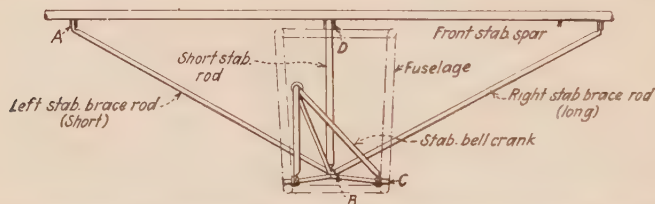


FIG. 24.—Stabilizer connections—sectional view through fuselage looking from rear.

the lock ring on short-rod adjusting screw with pliers. Fasten with cotter pins. Fasten cover on inspection hole. Fasten the fixed end of the aileron interplane strut on upper aileron, adjusting the angle slotted clevis until ailerons are in line with wings. Tighten locknut.

Tail Set-up.—Fasten diagonal stabilizer brace rods (with short vertical push rod in center) on stabilizer bell crank, having the long rod on

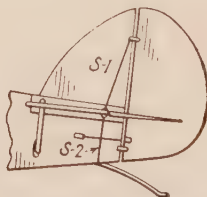


FIG. 25.—View of tail showing external brace wires.

the right-hand side as in Fig. 24. The end of the rod with the hole nearest the end should be on top. Fasten the stabilizer in place. Hook the elevator horn to long elevator push rod and lock with cotters. Fasten tail cover pan in place. Drive fin in place until holes in fuselage clip line up with holes in fin end, and then bolt in place. Mount

rudder in place. Adjust rudder wires so that rudder is in neutral position. Safety wire the turnbuckles. Be sure that the bolts holding the stabilizer to the stabilizer brace rod, Fig. 24, are tight and cottered. The small bolt in the stabilizer guide (this means the clips on the stabilizer that ride up and down on the vertical rod) should be snug, and cottered. External brace wires of the tail are shown in Fig. 25. Fig. 26 shows connections for stabilizer spans and braces.

Instructions for preparing the Waco Oleo landing strut for use are given in Fig. 27.

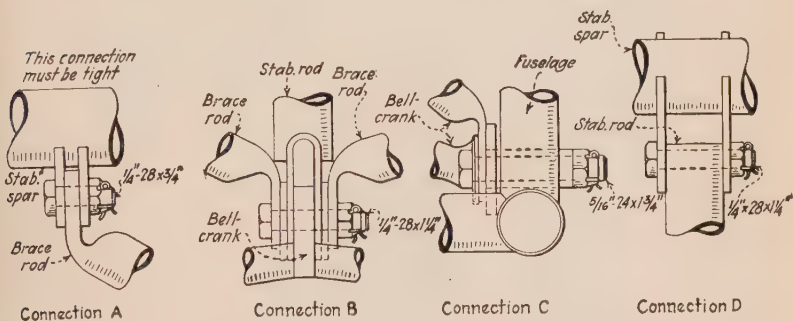


FIG. 26.—Connections for stabilizer spans and braces.

Repairing Metal Floats and Hulls.—According to K. D. Vosler, Superintendent of the Edo Aircraft Corporation, it is an easy matter to repair a metal float or flying-boat hull and it can be done by any good mechanic in the manner described. The forward portion of the bottoms are usually thick enough to resist puncture although frequently dented. If, however, a hole is punched in a sheet, as in Fig. 28, the repair is not difficult.

Examine the sheet carefully for tears radiating from the edge of the hole, such as at A. Cut the sheet away so that no damaged material remains. The sheet may be cut with tin snips or even a hacksaw blade in restricted quarters. File all edges smooth. For the sake of appearance the hole should be made round or square but this is unimportant. If it is necessary to bend the material, make the radius as large as possible. Figure 29 shows the damaged part cut away, while Fig. 30 shows the repair patch riveted in place over the hole. The patch is

To Prepare Oleo for Use.

1. Pull piston out of cylinder and remove auxiliary piston.

2. Fill tube up to 6 inches from top with G. E. transformer oil No. 6.

3. Insert auxiliary piston with bolt head down.

4. Insert main piston.

If Oleo is completely disassembled assemble as follows.

1. Assemble washer, long valve spring and bolt into main piston with ear on spring sticking out to keep spring from passing through hole in washer. If parts are new, grind washer into piston with valve grinding compound.

2. Attach check wire chain to shackle brazed to piston tube.

3. Insert piston into stream-line.

4. Assemble washer, short valve spring, and bolt into auxiliary piston as in Paragraph 1.

5. Hold tube upright and insert outer and inner shock springs.

6. Insert shock spring washer.

7. Fill tube up to 6 inches from top with G. E. transformer oil No. 6.

8. Insert auxiliary piston with bolt head down.

9. Insert main piston.

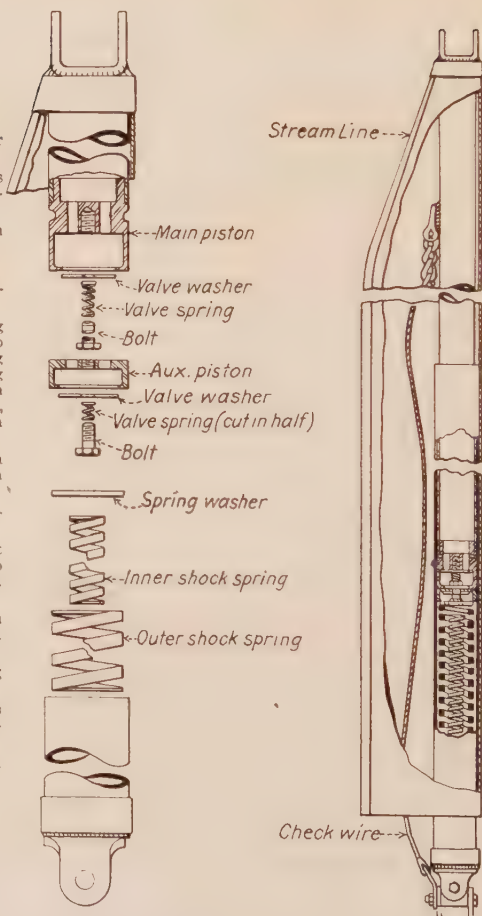


FIG. 27.—Waco Oleo landing strut.

cut from an aluminum alloy sheet one or two gages heavier than the damaged sheet, with an allowance of $\frac{1}{2}$ inch all around for riveting. The line of rivets is $\frac{1}{4}$ inch from the edge of the patch.

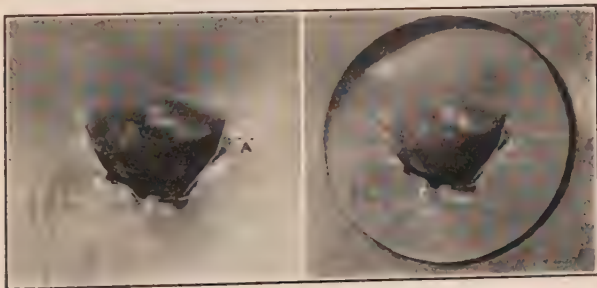


FIG. 28.

FIG. 29.

FIG. 28.—Hole punched in float.

FIG. 29.—Damaged portion cut away.

In the repair job illustrated the rivets were $\frac{3}{32}$ inch in diameter and spaced $\frac{3}{8}$ inch center to center. The table below is a guide as to thickness of sheet and patch, rivet diameter, and spacing.

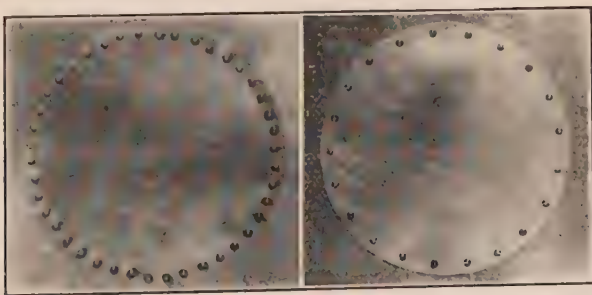


FIG. 30.

FIG. 31.

FIG. 30.—Repair patch riveted in place.

FIG. 31.—Temporary repair with machine screws.

After the rivet holes are laid out on the patch, it is placed in correct position over the hole and the holes drilled through both patch and sheet at the same time. A few machine screws will hold the patch in place during the riveting. It is advisable to use rivet sets and to

hold the rivet firmly from the back side during riveting. Rivets can be peened over by hand, however. It is advisable to cover all the overlapping surfaces with red lead before riveting to insure water-tight joints.

A temporary repair can be made with machine screws, as shown in Fig. 31, although riveting is preferred. The patch is the same as for riveting, the difference being that a second patch is placed on the other side of the sheet and the center distance of the holes is twice as great as for riveting, or $\frac{3}{4}$ inch, center to center. The two patches clamp the sheet between them, the machine screws being inserted from the outside. Some builders are now using screws in new work.

The following proportions for thickness of patch for different gages of metal sheets and the best rivets and rivet spacings, will be found useful:

TABLE OF SHEETS, PATCHES AND RIVETS

Thickness of sheet, inches	Thickness of patch, inches	Diameter of rivet, inches	Rivet spacing, inches
0.020	0.032	$\frac{3}{32}$	$\frac{3}{8}$
0.025	0.040	$\frac{3}{32}$	$\frac{3}{8}$
0.032	0.050	$\frac{1}{8}$	$\frac{1}{2}$
0.040	0.064	$\frac{5}{32}$	$\frac{5}{8}$
0.050	0.064	$\frac{3}{16}$	$\frac{3}{4}$
0.064	0.064	$\frac{3}{16}$	$\frac{3}{4}$

SECTION IV

CHAPTER 1

THE AIRPLANE ENGINE

Without going into the details of the design of airplane engines, it is well to have a general idea as to how the problem differs from that of the automobile engine. The main differences are that the engine must be capable of running at its maximum power for long periods at varying altitudes that affect fuel volume, compression, and engine temperatures. The weight must also be as light as possible, this varying from less than 2 to 5 pounds per horsepower. As the average automobile engine usually runs at from 15 to 25 per cent of its maximum power, the difference may easily be imagined.

Ignition and spark-plug troubles are also more frequent on the airplane engine, owing to this constant demand for high power, and these points may well be carefully studied.

There is a constant tendency toward higher engine speeds so as to increase the horsepower per pound of weight. This frequently necessitates the gearing down of the propeller, which, however, introduces engineering difficulties. According to present practice, from 1,500 to 2,000 seems to be the best speed for the propeller, and many engines are designed for those speeds so as to drive direct. Some, however, are now being run at as high as 2,800. This high speed involves careful consideration of metals to be used and such details as valve openings and manifold areas. Increased speeds may reduce the weight per horsepower even lower.

At the present time, most engines are made with cylinders of steel made either from tubing or forgings. Nearly all of the air-cooled cylinders are made from steel. The question of piston material seems to have been decided in favor of aluminum. As a basis for comparison with automobile engines, it is well to remember that in the airplane engine,

even at a speed of 1,800, a cylinder 5 by 5½ inches must deliver 25 horsepower. The tests required by the Department of Commerce are given on page 596. Briefly it is a 50-hour block test of which 5 hours must be at full throttle.

EFFECT OF ALTITUDES

The difference in temperature at different altitudes is a problem peculiar to the airplane engine. The low temperature of a high altitude cools the engine excessively at times, and this is particularly bad when diving. As the engine is shut off to dive, it cools still more, in spite of the decreasing altitude; and when power is thrown on again at the new level, the comparatively cold engine is not lively and will not develop full power at once.

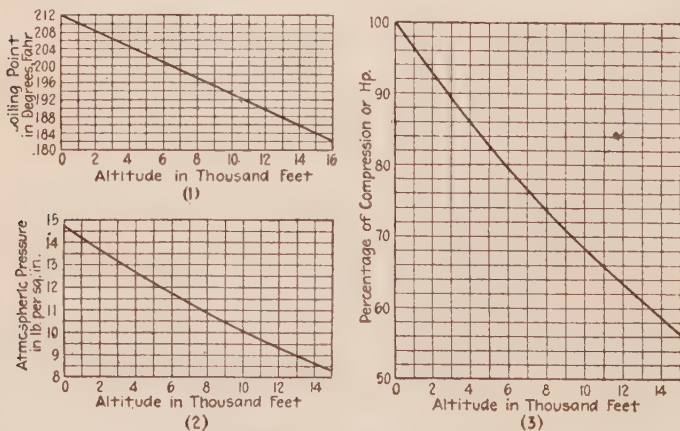


FIG. 1.—Effect of altitude on engines.

The most serious effect of altitude flying, however, is that caused by the loss of power due to the reduction of atmospheric pressure at high altitudes. For instance, at an altitude where the density of the air is only half as great as at sea level, the velocity required for sustentation is increased 41.4 per cent and the effective horsepower required to maintain this speed, also, is 41.4 per cent greater. To overcome this difficulty, "superchargers" are installed on the airplane engines

which cause them to maintain their rated horsepower regardless of altitude. These supercharges are, in reality, blowers which give the carbureter intake air at the same pressure which it gets at sea level. The Moss supercharger is probably the best known of any. It is an air turbine operated from the engine exhaust and has been used on several altitude record flights. The Lewis supercharger, designed by Dr. George W. Lewis of the National Advisory Committee for Aeronautics, is of the centrifugal type and is operated by gears from the crankshaft of the engine.

The effect of both temperature and atmospheric pressure are shown in diagrams 1 and 2 of Fig. 1, the boiling point affecting both air- and water-cooled engines.

The effect of altitude on the horsepower of the engine is seen in diagram 3 which shows decrease of power up to 15,000 feet, at which point it is seen to be a trifle over 56 per cent of the horsepower developed at sea level.

The World War demonstrated the necessity and advantages of high-altitude flying to such an extent that great strides have been taken further to perfect this aspect of aeronautical engineering. It has been found that, in many instances, strong winds blowing in directions which are advantageous to commercial airplane routes are found only at altitudes of 20,000 feet and higher. In order to take advantage of these winds, the airplanes used under these conditions must be equipped quite differently from those used in ordinary service.

High-compression motors are used which give more power at high altitudes than the ordinary motor because of the fact that their compression is greater at those heights. When these motors are equipped with superchargers, their power output at 30,000 feet is nearly as great as at sea level. This mechanism eliminates much of the objection to altitude flying, and with its further development we may expect to see the scope of high-altitude flying greatly increased.

U. S. Army Air Corps engineers have experimented with ethylene glycol as a coolant for water-jacketed engines instead of water. This chemical is the base for antifreeze solutions but is used direct in radiators of Army planes in tests. Its boiling point is very much higher than water and so permits an engine to be run at higher and more economical temperatures. It is also said to permit a reduction of 75 per cent in the weight of radiators and cooling liquid. Joints and

packing glands must be kept tighter than for water and a closed cooling system must be used.

FIRING ORDERS OF INTERNAL-COMBUSTION ENGINES

Many people have trouble in figuring out the firing order of an automobile or airplane engine but the following system will show how easy the whole thing is. This system is based on the usages of common practice and may not cover all the freak engines that have been built and made to run. There are also a few exceptions to the general practice.

The simplest multicylinder engine in general use is of the four-cylinder type. This type is now only used in small airplanes, but it serves to show the firing order of eight-cylinder engines. Experience has proved

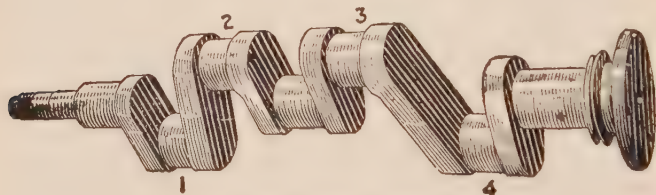


FIG. 2.—Four-cylinder crankshaft.

that a crankshaft with the other crankpins, 1 and 4, in line with each other, and with the inner ones, 2 and 3, in line with each other, but 180 degrees away from the outer ones, gives the best results. Figure 2 shows such a shaft. With this arrangement, it is evident that a four-cylinder, four-cycle engine can fire only two ways, either 1-2-4-3 or 1-3-4-2, for the impulses occur at intervals of 180 degrees of crankshaft revolution. The duration of the four-stroke cycle is 720 degrees, and the interval for even spacing will be 720 degrees divided by the number of cylinders.

The eight-cylinder, V-type firing order naturally comes next as it is based on either one of the four-cylinder orders just mentioned and because the eight uses the same shaft as the four, two connecting rods being attached to each crankpin instead of one.

There are various methods of designating cylinders. In the four, this does not make so much difference, for the same result is arrived

at no matter which end you start from. There is little doubt that the best and most logical method in the V-8 to follow is to number the cylinders from 1 to 4 right and from 1 to 4 left, commencing from the starting-crank end of an automobile engine and from the end opposite the propeller end, of an airplane engine. This makes the output end of each engine the one with the highest-numbered cylinder nearest to it. Figure 3 shows diagrammatically this system of numbering applied to eight-cylinder engines.

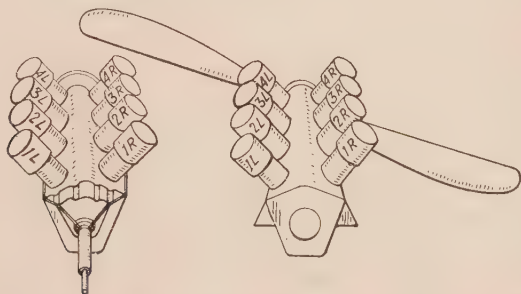


FIG. 3.—Eight-cylinder automobile and airplane engines.

FIRING ORDERS OF AN EIGHT

Assuming that the cylinders are numbered this way and the cylinder blocks are inclined at 90 degrees, we can evolve two firing orders from each four-cylinder firing order. The firing interval will be 90 degrees, and the firing order will alternate between the two blocks. The easiest order to work out will be obtained when opposite cylinders, that is, the ones whose connecting rods are fastened to the same crankpin, fire consecutively. Application of this principle gives two firing orders, 1L-1R-2L-2R-4L-4R-3L-3R and 1L-1R-3L-3R-4L-4R-2L-2R.

Reference to Fig. 3 will show that, instead of firing opposite cylinders, such as 1L and 1R, we could fire cylinders whose rods come to different pins which are in line, for example, 1L and 4R or 2L and 3R. The only changes necessary in the engine would be in the camshaft and wiring. The other two firing orders are, then, 1L-4R-2L-3R-4L-1R-3L-2R and 1L-4R-3L-2R-4L-1R-2L-3R. It is probable that the engine balance is slightly better with either of these arrangements than with the first two mentioned.

So far nothing has been said about the direction of rotation of the crankshaft. In automobiles, the rotation is clockwise when the observer stands in front of the car, except in a very few cases.

DIRECTION OF ROTATION OF AN AIRPLANE ENGINE

When it comes to airplane engines, all sorts of contradictory ideas are encountered. With a direct-drive tractor, the usual way is to call the motor a clockwise motor, if the pilot, as he sits in his seat looking

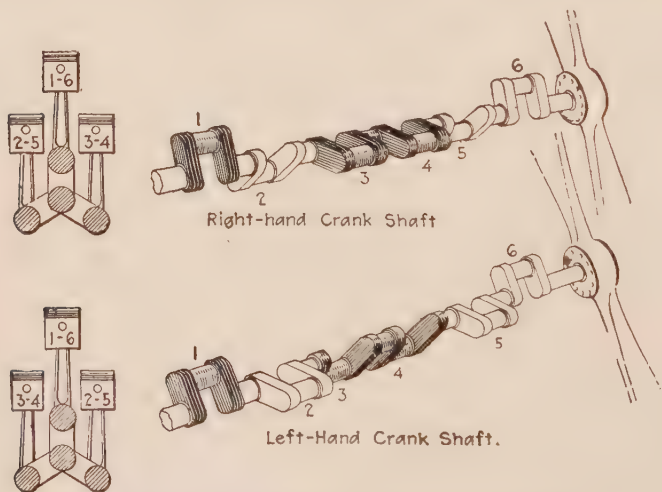


FIG. 4.—Right- and left-hand six-cylinder crankshaft.

forward along the cylinders, sees the propeller describing clockwise circles. If the propeller is driven through reduction gearing, the question arises as to whether to judge by the rotation of the propeller or of the crankshaft. It would seem better to judge by the crankshaft, although this is not the usual practice, because the type of reduction gearing used on the Rolls-Royce drives the propeller in the same direction as the crankshaft rotation, although this is not always the case.

Still further confusion resulted when the rotating cylinder type had to be taken into account. The observer stands in front of the airplane and determines the direction of rotation from that position. Conse-

quently, a counter-clockwise Gnome engine would rotate a propeller in the same direction as a clockwise Liberty engine.

The direction of rotation is usually decided from the crankshaft end, the observer standing in front of the engine, that is at the end opposite the propeller. This understanding will help in the consideration of 6-, 12-, and 18-cylinder engines, all of which use the same type of crankshaft.

Six-cylinder crankshafts are built in two ways, which are arbitrarily called *right hand* and *left hand*, this distinction having nothing whatever to do with the direction of rotation. Figure 4 shows views of both arrangements of crankpins. When the observer stands in front of a right-hand crankshaft which has been rotated so that crankpins 1 and 6 are vertically upward, he will see the center crankpins 3 to 4, to the right of the center line and 2 to 5 to the left. This is reversed for the left-hand shaft.

The crank arms are at 120 degrees to each other to give even firing angles of 120 degrees. This value is determined as before by dividing the total duration of the cycle, 720 degrees, by the number of cylinders. A glance at Fig. 4 will show that the number of possibilities in the firing order of the cylinders is greater than with the simpler crankshaft. If the right-hand shaft is rotated clockwise, the cylinders could be fired in the two orders 1-2-3-6-5-4 and 1-5-3-6-2-4. Experience has shown, however, that it is not advisable to fire adjacent cylinders consecutively, and, consequently, the first arrangement can be eliminated as unsatisfactory. The second arrangement is then the one to be expected when the shaft under consideration is a right-hand and rotates clockwise. A little study will show that it is also the firing order of the left-hand shaft turning counter-clockwise.

It might be well to mention at this point the ways of determining the direction of rotation of the crankshaft. If the engine is assembled, it is necessary only to turn the shaft slowly by hand, watching the valves on any one cylinder during the process. If the inlet valve is seen to open immediately after the closure of the exhaust valve, the direction of rotation is correct.

With the engine disassembled, an inspection of the camshaft to determine the relative positions of the cams which open the valves of any one cylinder will answer the question. The relative directions of rotation of the camshaft and crankshaft due to the type of gearing used must be taken into consideration, as in the average L-head motor

the directions are opposite, while in some overhead-valve types they are the same.

Returning now to the right-hand crankshaft—if it is rotated counter-clockwise, the firing orders 1-3-5-6-4-2 and 1-4-2-6-3-5 are the result. The first is bad, because 2 and 1 and 5 and 6 are together. The other is the conventional one and will also apply to the left-hand shaft when rotating clockwise. This exhausts the reasonable possibilities and leaves only practical firing orders, 1-5-3-6-2-4 and 1-4-2-6-3-5.

Just as the V-type eight is a double four, so the V-type twelve is a double six or "twin six," as it is sometimes called, and uses a six-cylinder crankshaft, either right or left handed. The direction of rotation is ordinarily clockwise, although some airplane engines for multi-engined machines turn counter-clockwise to equalize the torque.

The normal firing angle of the V-type 12 is, of course, 60 degrees, but in some airplane engines, the Liberty, Renault, and Lancia, for example, this angle has been reduced to cut down the width and, consequently, the head resistance of the engine. This sacrifices the even firing angle but apparently has no particularly detrimental effect on the running of the engine. The change, however, has nothing to do with the firing order.

If the cylinders are numbered as were those of the eight, from 1 to 6 right and 1 to 6 left, and the same reasoning applied, four 12-cylinder firing orders are obtained, as follows: 1L-1R-5L-5R-3L-3R-6L-6R-2L-2R-4L-4R, 1L-1R-4L-4R-2L-2R-6L-6R-3L-3R-5L-5R, 1L-6R-5L-2R-3L-4R-6L-1R-2L-5R-4L-3R, and 1L-6R-4L-3R-2L-5R-6L-1R-3L-4R-5L-2R.

The third one is in most common use, as most 12-cylinder engines use right-hand shafts turning clockwise.

This development may go one step further and take in the 18-cylinder W- or broad-arrow type, which is essentially a V-type 12 with an extra row of six cylinders down the middle. Assuming that a right-hand, clockwise crankshaft is used, the firing order of this type may be readily worked out if one other fact about it is known, that the cylinders opposite each other on the outside banks fire in the same group with the center cylinder whose rod comes to the other crankpin in line; that is, 1L and 1R, whose connecting rods come to crankpin 1, fire in the same group with 6C, whose rod comes to crankpin 6. The firing angle is 720 degrees, divided by 18, or 40 degrees, and the angles between the cylinder blocks are 40 degrees as shown in Fig. 5.

If the plan just outlined is followed through, the following firing order can be obtained: 1L-6C-1R-5L-2C-5R-3L-4C-3R-6L-1C-6R-2L-5C-2R-4L-3C-4R. This makes use of the standard method of cylinder numbering and is comparatively easy to remember or work out. The maker numbers the cylinders in the manner shown in Fig. 5, and his method of numbering makes the firing order read 1-7-13-5-11-17-3-

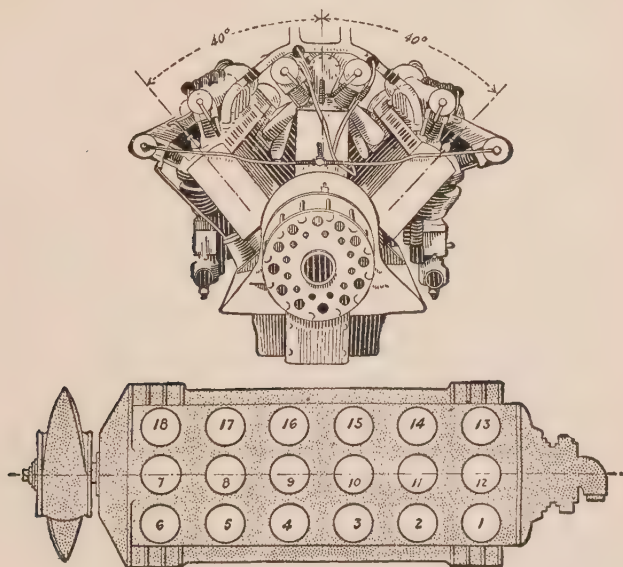


FIG. 5.—The 18-cylinder W-type airplane engine.

9-15-6-12-18-2-8-14-4-10-16. There is apparently no rhyme or reason to this, although it is just the same as the other one and it would take a memory expert to figure out a scheme by which to remember it without chance of mistake.

The X-type of engine uses the same crankshaft as a V-engine and the firing order can be considered in the same way.

Single-row radial-engine cylinders are numbered clockwise when looking from the pilot's seat toward the propeller. Number 1 cylinder is at the top. The firing order begins with No. 1 and follows with each

second cylinder. Thus the firing order of five-, seven- and nine-cylinder engines will be 1-3-5-2-4, 1-3-5-7-2-4-6, and 1-3-5-7-9-2-4-6-8.

Double-row radial engines have a two throw crankshaft and so are equivalent to two single-row engines in tandem. The cylinders may be staggered, as in the Curtiss Challenger, or tandem, as in the Curtiss Chieftain. Both the number of cylinders and firing order differs from single-row engines and the reader is referred to the descriptions of the engines named for details. The Curtiss Challenger, for example, fires 1-3-2-4-6-5, while another double-row radial fires 1-6-5-4-3-2. The firing order of the Chieftain can only be shown by an illustration as given on page 93.

TYPES OF AIRCRAFT ENGINES

Engines, as with everything else connected with aircraft development, are undergoing constant change and improvement. New engines are being designed and built, while some of those that were fairly successful in the past have disappeared, or are being discarded. The Gnome, and Le Rhone engines, which revolved with the propeller, are no longer used. The Hispano-Suisa, or Hissso, is no longer built in this country, although enough still remain in service to warrant its illustration. The use of the Liberty engine is now practically confined to Army and Navy planes. While an excellent engine in its day, and still used to some extent abroad, it has almost disappeared from commercial use in this country. Of these engines only the Hissso is, therefore, included in this edition.

The old Curtiss OX-5 engines, on the other hand, are still being used to a considerable extent, in spite of the fact that they are no longer being manufactured. For, while new engines of approximately the same power are now being made and will eventually replace the OX-5 engine, so many of these are still in use that it seems advisable to retain a rather complete description of the engine itself, and of the methods used in caring for the engines in service. In fact, the growing scarcity of the OX-5 engine has resulted in much greater care being taken to keep them in good condition. A few years ago the price of these engines was so low that it hardly paid to overhaul them. This condition no longer exists, and it seems probable that many will continue to be used for several years.

The tendency at present is unmistakably toward the air-cooled engine. Very few water-cooled engines are now being built in this country. Those still in production are for the most part of comparatively high power, 500 horsepower, or over. Even in this high-power field the air-cooled engine is making considerable headway. Examples of large air-cooled engines are the Hornet, the Cyclone, the Chieftain, and the Jupiter.

The successful air-cooled engines originating in this country have cylinders located radially around a central crankcase and crankshaft. These cylinders are stationary, however, and while the engines resemble the Gnome engine in general appearance, they are very different in principle and operation. The usual design of radial engine has a single-throw crankshaft and all the cylinders are in one plane, or bank. This arrangement is varied in some cases, however, by using a double-throw crankshaft and having two banks of cylinders.

Radial engines having a single bank of cylinders have an odd number of cylinders in order to secure the desired firing order of the cylinders. Engines of three, five, seven, and nine cylinders are very common. When two banks of cylinders are used, however, as in the Curtiss Challenger and Chieftain, the engine has an even number of cylinders because each bank has an odd number. The Challenger engine, for example, is really two three-cylinder engines in tandem, giving a total of six cylinders.

It is characteristic of radial engines to have but one main connecting rod on each crank to which all the others are attached. These main rods are called master or mother rods, and they alone bear on the crankpin. The other rods bear on separate pins held in the sides of the master rod, as will be seen in the details shown with the different engines. In some designs of radial engines, such as the Pratt and Whitney and the Velie, the master rod is solid instead of having a cap bolted to the rod itself as is usual in most engines. In such cases the rod is put over the crankpin, the pin being specially designed, in two parts, one going inside the other, and is splined or otherwise machined accurately to prevent movement when in operation. On other and smaller engines a somewhat simpler design is used.

While mechanical details naturally vary considerably in engines of different makes, there is enough similarity in them to make it unnecessary to go into minute details with all the engines now available. A few

typical engines have been selected, of different sizes, and these, together with a general description of the others, will be found sufficient to make their operation and maintenance clear to the user or mechanic. This similarity, rather than any desire to discriminate, accounts for the omission of details in some cases.

While the radial-cylindered engine predominates in the air-cooled field, there are a few air-cooled engines with the cylinders in line. These are usually four-cylinder engines in sizes not exceeding 100 horsepower. Some of these engines have been very successful in small planes; the Australian flight of Sir Allan Cobham and the South African flight of Lady Heath, being made with engines of this type. While most of the engines of this type are of British origin, there are a few made in this country of both American and British design.

Barrel-type engines, in which the cylinders parallel to a central shaft, as with the chambers of a revolver, have been built for many years, both for steam and gasoline. None have been sufficiently successful to remain in service and the type is not in practical use.

Vertical engines are but little used and are confined to small powers, usually with four cylinders. These are both air and water cooled. The V-type engines are usually water cooled although some Liberty engines have been converted to air cooling. The X- and W-engines are water cooled. Radial engines are all air cooled.

The Packard engine, described in detail in the previous edition is now omitted because it has not found its way into commercial use. The same is true of the Curtiss D-12 engine previously described. In its place, however, is the new Curtiss Challenger and Chieftain engines, both of the radial type, which is described in some detail.

The Packard Motor Car Company is developing a radial air cooled engine of the Diesel type, designed by Capt. J. M. Woolson and Henri Krebs, that weighs approximately 3 pounds per horsepower but no details are available as yet. The Diesel engine has many advantages, such as eliminating the magneto or other electrical ignition system as the charge is ignited by the compression in the cylinder. Each cylinder has a small fuel pump that injects fuel into the cylinder at the proper time, eliminating the carbureter as well. The failure of a fuel pump only cuts out one cylinder, leaving all the rest in service. Then, too, the heavy oil used as fuel greatly reduces the fire hazard and the absence of the ignition spark greatly simplifies the utilization of radio

on the plane. The successful development of the Diesel engine in weights low enough to permit use in airplanes will be a distinct advance in aircraft construction.

Nothing has done more to make possible the great advances in aviation than the improvement in engine design and the decrease in weight per unit of power. While the weight of engines of small power has not decreased to a marked degree, the higher powered radial engines have reached an average weight of 1.4 pound per horsepower, a decrease of approximately one-half in 10 years. One engine, the Bristol Mercury, of 900 horsepower, weighs 11 ounces per horsepower. Better designing, better materials, and higher speeds, have all contributed to make these results possible. And in spite of the reduction in weight, the engines of today are more reliable than ever before.

There are also other engines available than those illustrated in this edition. Some of them have not yet been used in sufficient quantities to make it seem advisable to include them in this volume. With few exceptions they are sufficiently like some of the engines shown to make the same suggestions as to servicing them of value to the user.

At least 50 different aircraft engines are reported in various stages of development, most of them weighing less than 4 pounds per horsepower with about one-third of them weighing $2\frac{1}{2}$ pounds per horsepower or less. Some of the larger powered engines weigh much less than this. The price per brake horsepower ranges from \$25 per horsepower for small engines to \$15 per horsepower for large engines. As new engines become established they will receive proper attention.

Among the recent refinements are finer pitches of cooling fins on air-cooled engines, radio-shielded spark plugs, better magneto mountings, lighter reduction gears and other features. Superchargers are coming into greater use, some of them, such as the General Electric exhaust gas-turbine type, showing very satisfactory durability, having been in service for over a year with several hundred hours of flying, without failure.

The construction of air-cooled engines varies to some extent with the horsepower developed. Small engines, developing from 10 to 15 horsepower per cylinder, frequently use a cast cylinder, the metal varying from cast iron to chrome or nickel-steel alloys in the mixture. The fins are usually cast integral with the cylinders and not machined. Practice differs as to the cylinder heads. In a few cases, the head is cast integral with the cylinder barrel to avoid joints. In others, the head is of

aluminum or some of its alloys, usually with bronze rings cast in place to form the valve seats. The heads are generally shrunk on the cylinder, being bored slightly smaller than the fit and expanded by heat before putting in place. When it cools it grips the cylinder firmly, but in addition it is held by either the screw threads that form part of the fit, or by bolts in some cases. The mating surfaces are usually both plain and threaded, the head being screwed on while hot in such cases and no bolts being used.

In larger engines the cylinder barrels are made of alloy steel forgings with the cooling fins carefully turned on the outside. In prewar manufacture, steel cylinders were bored out of a solid bar of forged billet, the boring and turning removing between 80 and 90 per cent of the weight of the original blank. Modern methods use hollow forgings and greatly reduce the waste of both metal and of machining time. All large engines have separate heads of aluminum alloy, nearly all being shrunk on with both a plain and threaded fit. One engine, however, bolts the head against a flat surface on the end of the cylinder barrel.

ENGINE OPERATING COSTS

Actual operating costs are of interest and value to those engaged in or contemplating air transport. The figures that follow were recently compiled by the Wright Aeronautical Corporation from 91 Whirlwind engines in service on nine leading airlines. Complete data were not available on all counts, the cost of replacement parts, for example, only covering 37 of the 91 engines, the other 54 engines having required no replacements at the time the figures were secured. The cost of operation will vary both with the conditions under which the lines operate and the efficiency of the system of maintenance. Although the average in the table of the hours flown before the first overhaul is 290 hours, one operator reports 583 hours, another 450 hours, while a third gets about 200 hours. One of the engines in this group has flown over 2,000 hours and another over 1,600 hours.

Assuming 100 miles per hour as an average performance, the maintenance figures about \$1.30 per hour of flying or \$0.013 per mile. Depreciation, based on 2,000 hours engine life and \$5,000 initial cost, is \$2.50 per hour or \$0.025 per mile. Fuel and oil costs at \$0.18 and \$0.75 per gallon total \$2.82 per hour or \$0.028 per mile, making a total of about \$6.62 per hour or \$0.066 per mile.

Engine Cowling—N. A. C. A. No. 10.—Tests by the engineers of the National Advisory Committee of Aeronautics show that the shape of engine cowling has a serious effect on the resistance of the plane in flight. The type of cowling in Fig. 6 has been shown to have much less resistance than those generally used. The general conclusions that follow give the result of their experiments.

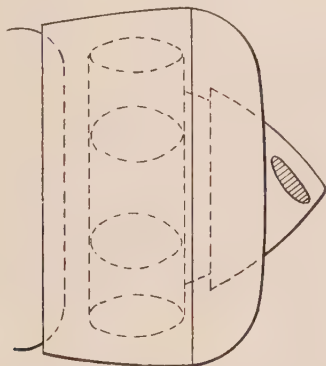


FIG. 6.—Outline of N. A. C. A. cowling.

First.—The drag of an average sized cabin fuselage with the engine removed and the nose rounded is tripled by placing an uncowled Whirlwind J-5 engine on the nose.

Second.—With the conventional forms of cowling, in which a portion of the cylinders and valve gear is exposed, the drag becomes less as the cowling is increased, but even in the most extreme case the reduction amounts to only about 23 per cent of the increase in drag due to an uncowled engine.

Third.—A spinner, if used in front of a radial engine, decreases the drag but a very small amount, and has an almost negligible effect on the performance of an airplane.

Fourth.—With a cowling similar to No. 10, which covers the entire engine and separates the cooling air from the general flow about the body, the reduction in drag is about 60 per cent of the increase due to an uncowled engine. This is about 2.6 times as great with the best conventional form of cowling.

Fifth.—The use of cowling similar to No. 10 seems entirely practical as regards both cooling and maintenance under service conditions. It must be carefully designed, however, to cool properly.

CHAPTER 2

THE CURTISS CHALLENGER ENGINE

The Curtiss Challenger engine is of the six-cylinder, air-cooled radial type conservatively rated at 170 horsepower at 1,800 r.p.m. (Figs. 1 and 2). It is equivalent to two three-cylinder engines mounted in tandem, having a two-throw crankshaft to secure dynamic balancing. The stroke is shorter than the bore to keep the diameter small and so reduce head resistance and improve the pilots vision. Each set of three cylinders is fed from each barrel of a double carbureter through a simple manifold cast in the crankcase. The engine develops over 0.3 horsepower per cubic inch of displacement and weighs less than $2\frac{1}{2}$ pounds per horsepower.

The crankcase is cast in two halves of aluminum alloy, both ends being shown in Figs. 3 and 4. Figure 5 shows both halves with studs in place. The cylinders are of forged steel with heat-treated aluminum-alloy heads screwed and shrunk on. Rocker boxes are cast integral with the cylinder heads (Fig. 6). There are two valves per cylinder, seating on bronze inserts in the head.

The connecting-rod construction differs from that of most radial engines as seen in Fig. 7. The cap of the master rod carries the other two rods of the set. Rods are of heat-treated steel with babbitt-lined steel-backed bearings in the master rod and bronze bearings in the short rods. The crankshaft assembly is shown in Fig. 8 where the two throws and the way in which the rods go in place can be clearly seen. The pistons are of aluminum alloy and have five rings. Piston pins are full floating with aluminum caps at the end. In Fig. 9 all rods are in place. Lubrication is of the pressure and scavenging type. A pressure pump feeds the oil tank through a fine screen in a small pressure chamber to the main bearing, which is used as an oil seal. This screen acts as a valve so that if the oil is too thick, as it may become in cold weather, the screen will lift from its seat and let the oil flow around it. A single scavenging pump removes oil from the sump and returns it to the oil tank. The pressure and the scavenging screens, oil drain plug, and oil thermometer well are in this sump. General dimensions are shown in Fig. 10. The firing order is 1-3-2-4-6-5. The cylinders are numbered as in Fig. 11. The Chieftain engine cylinders are numbered as in Fig. 12.

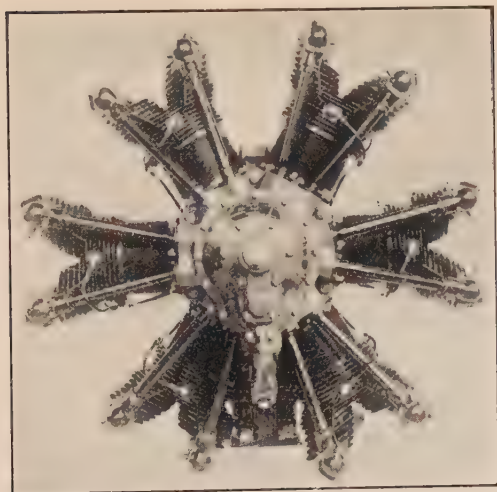


FIG. 1.—Propeller end of Challenger engine.

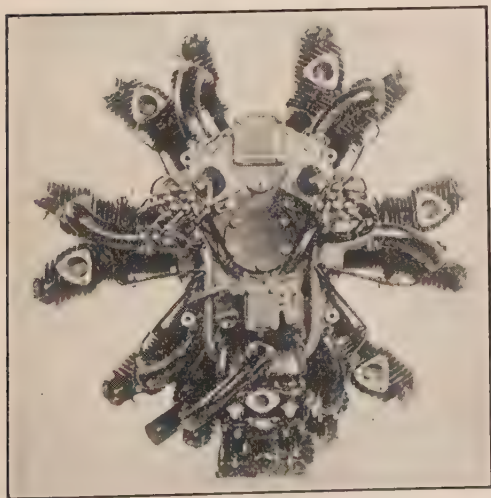


FIG. 2.—Magneto and carburetor end; Challenger.

GENERAL SPECIFICATIONS

Rated horsepower.....	170 horsepower at 1,800 r.p.m.
Maximum horsepower at sea level.....	180 horsepower at 1,800 r.p.m.
Compression ratio.....	5.2 to 1
Displacement of Engine.....	603 cubic inches
Bore.....	5½ inches
Stroke.....	4¾ inches
Type of piston.....	Aluminum, ribbed head
Number of compression piston rings.....	2 per cylinder
Number of oil control piston rings.....	3 per cylinder
Ignition system.....	Two single-spark high-tension magnetos
Carbureter (type).....	Stromberg NAU-4J dual carbureter
Desired oil temperature under normal operation, inlet.....	140° F.
Oil pressure desired (minimum with oil outlet at 160° F.) at 1,800 r.p.m.....	100-120 pounds, per square inch gage
Oil pressure desired (minimum with oil outlet at 160° F.) at 1,600 r.p.m.....	80-100 pounds, per square inch gage
Grade of oil desired.....	Vacuum, Gulf, Penzoil or pure oil of proper grade for the season
Oil consumption—pounds per brake horsepower per hour.....	.025
Fuel consumption—pounds per brake horsepower per hour	
Rated power.....	.55
Cruising.....	.50
Pressure of fuel supply (pounds per square inch).....	3 to 5
Rotation of propeller.....	Clockwise
Speed of tachometer shaft.....	½ crankshaft
Firing order.....	1, 3, 2, 4, 6, 5
Approximate hours before overhaul.....	200
Weight of engine without starter, fuel pump, generator and gun control, but with exhaust heat equipment, exhaust flanges, exhaust flange, flange gasket, and flange nuts.....	420.0 pounds

GENERAL SPECIFICATIONS.—(Continued)

Overall diameter.....	41 $\frac{3}{4}$ inches
Length from end of propeller shaft to mounting plate.....	27 $\frac{7}{16}$ inches
Length from mounting plate to end of generator.....	111 $\frac{7}{32}$ inches
Lengths from mounting plate to end of magneto.....	72 $\frac{3}{32}$

SUMMARY OF CLEARANCES
(Challenger engine)

	Minimum	Desired	Maximum	Allowance before replacing or readjusting
Camfollower—diametrical clearance in guide.....	0.0005	0.0015	0.0025	0.005
Camfollower roller pin—diametrical clearance in bushing.....	0.000	0.001	0.002	0.003
Camfollower roller bushing—diametrical clearance in roller.....	0.0005	0.001	0.002	0.003
Camfollower roller—side play in follower.....	0.0085	0.012	0.0155	0.025
Cam gear adjusting shaft—diametrical clearance.....	0.001	0.002	0.003	0.005
Cam gear—diametrical clearance on spacer.....	0.0025	0.0035	0.004	0.006
Connecting rod—diametrical clearance on crankpin.....	0.002	0.002	0.0025	0.005
Connecting rod—end play on crankpin.....	0.006	0.008	0.010	0.040
Connecting rod articulated—diametrical clearance on wrist pin.....	0.0000	0.0005	0.0015	0.003
Connecting rod articulated—end play in master rod.....	0.004	0.004	0.006	0.010
Crankshaft thrust bearing—diametrical clearance in case.....	0.0005	0.001	0.002	0.003
Crankshaft thrust bearing lock nut—diametrical clearance in cover.....	0.019	0.021	0.023	0.030
Crankshaft propeller end gear—diametrical clearance in case.....	0.003	0.0045	0.006	0.008
Crankshaft main ball bearing—diametrical clearance in case.....	0.002	0.002	0.003	0.004
Crankshaft spacer antipropeller end—diametrical clearance in case.....	0.006	0.007	0.008	0.010
Crankshaft position when cold—between main journal propeller end-bearing ring and side of cheek of crankshaft throw.....	0.213	0.218	0.223	
Gears—all accessory drive train backlash.....	0.015	0.015	0.025	0.035
Gears—cam drive (Except C-10046) backlash.....	0.003	0.005	0.010	0.030

SUMMARY OF CLEARANCES.—(Continued)
(Challenger engine)

	Mini- mum	Desired	Maxi- mum	Allowance before replac- ing or readjust- ing
Gear—drive shaft C-10046 backlash.....	0.015	0.020	0.025	0.035
Magneto drive intermediate gear—diametrical clearance in case.....	0.001	0.002	0.003	0.006
Magneto drive shaft—diametrical clearance in case.....	0.001	0.002	0.003	0.005
Oil pump live shaft—diametrical clearance in body	0.001	0.0015	0.002	0.005
Oil pump idler shaft—diametrical clearance in gears.....	0.001	0.002	0.002	0.005
Oil pump idler shaft—diametrical clearance in pump cover.....	0.0005	0.001	0.0015	0.003
Oil pump gears—diametrical clearance in body...	0.004	0.005	0.006	0.010
Oil pump small gear—end play in body.....	0.003	0.004	0.006	0.010
Oil pump large gear—end play in body.....	0.004	0.005	0.007	0.010
Oil pump intermediate drive shaft—diametrical clearance.....	0.001	0.002	0.003	0.005
Piston—diametrical clearance at top land.....	0.032	0.034	0.036	0.050
Piston—diametrical clearance at bottom of skirt.	0.025	0.027	0.029	0.042
Piston pin—diametrical clearance in piston.....	0.000	0.0005	0.001	0.003
Piston pin—diametrical clearance in connecting rod.....	0.000	0.001	0.0015	0.003
Piston ring—side clearance in groove top.....	0.0035	0.004	0.005	
Piston ring—side clearance in groove next to top	0.0025	0.003	0.004	
* Piston ring—side clearance in groove oil control rings.....	0.0015	0.002	0.003	
Piston ring—gap compression rings (scarf joint) ..	0.017	0.019	0.021	0.040
Piston ring—gap oil control rings.....	0.012	0.014	0.016	0.035
Rocker-arm bearing—diametrical clearance in cylinder head.....	0.0005	0.001	0.002	0.003
Rocker-arm bearing—diametrical clearance on pin.....	0.0000	0.0005	0.001	0.003
Rocker-arm—side play.....	0.017	0.019	0.024	0.030
Tachometer drive shaft—diametrical clearance...	0.001	0.002	0.003	0.005
Tappet exhaust valve—gap when cold.....	0.004	0.005	0.006	
Tappet intake valve—gap when cold.....	0.009	0.010	0.011	
Valve intake—diametrical clearance in guide.....	0.004	0.005	0.006	0.008
Valve exhaust—diametrical clearance in guide...	0.005	0.006	0.007	0.010
Wrist pin—clearance in master rod bushings.....	0.0005T	0.0000	0.001L	0.003L

* These rings do not have side clearance except between the oil control slots. At these points the ring is solid. At the slots the ring is expanded causing the ring to fit tight in the groove.

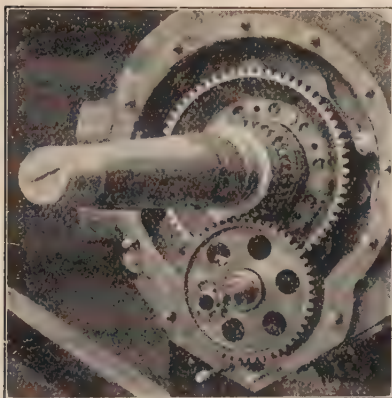


FIG. 3.—Propeller end with case removed.



FIG. 4.—Cover removed from other end.

OPERATION AND MAINTENANCE

A general inspection should be made before and after each day's flight. It is not necessary to remove spark plugs unless the action in operation indicates that there is a defective plug. All plugs should be inspected after every 10 hours of running.

In freezing weather the oil in the lubricating system should be drained immediately after flight while the engine is still warm. This, of course, is not necessary if the engine will not be idle long enough for the oil to

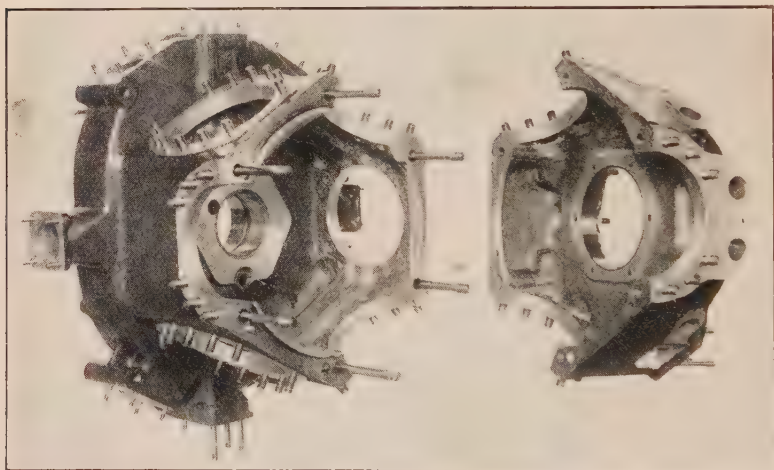


FIG. 5.—Both halves of crank case.

become cold. When making ready for flight if the oil is heated to at least 150° F., before putting it into the tank the engine will start much easier. This procedure will also eliminate a long period of time for "warming up" the engine.

After 10 hours of flight service check the magneto breaker points. They should be set with a gap of 0.012 inch. The breaker points must be kept clean and free from oil. Check the cylinder "hold-down" nuts and mounting flange bolts for tightness.

The tappet clearances should be kept at 0.005 inch for the intake and 0.010 inch for the exhaust when the engine is cold. Check the clearances every 10 hours.



FIG. 6.—Cylinder, heads and assembly.

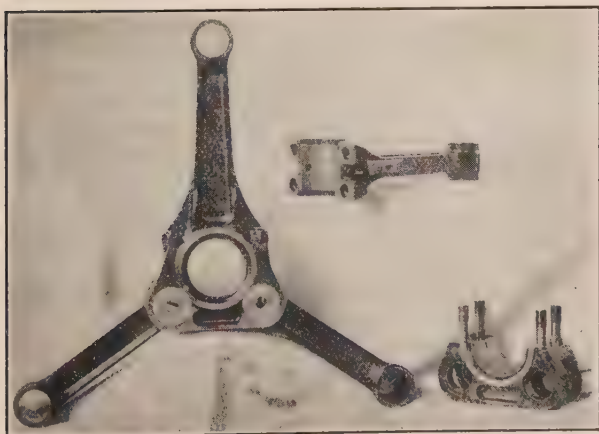


FIG. 7.—Construction of connecting rods.

Lubrication.—1. Lubricate the rocker arms each 5 hours with grade “600 W” oil.

2. Change the oil in the lubrication system every 10 hours.

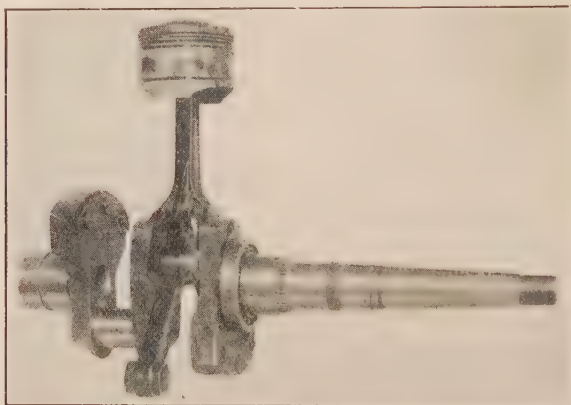


FIG. 8.—Connecting rods on one crank pin.

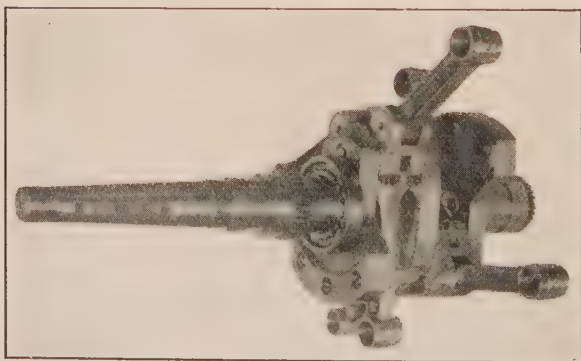


FIG. 9.—Both rods and bearings assembled.

3. Put five drops of light cylinder oil in the oil cups of the magnetos every 10 hours.

Inspection.—Before starting the engine make sure that all nuts and bolts are tight and all controls are in proper working order. Inspect

the engine-mounting bolts and the cylinder hold-down nuts for tightness. Check the propeller hub nut. Be sure it is tight and locked. Lubricate the rocker arms with "600 W" oil. Put in enough so that it can be seen to issue from the rocker. Make sure the oil and gasoline tanks are filled to the proper capacity, using oil as recommended and a grade of fuel equal to or better than domestic aviation gasoline. Check the throttle, altitude mixture, and spark controls. Make sure that the

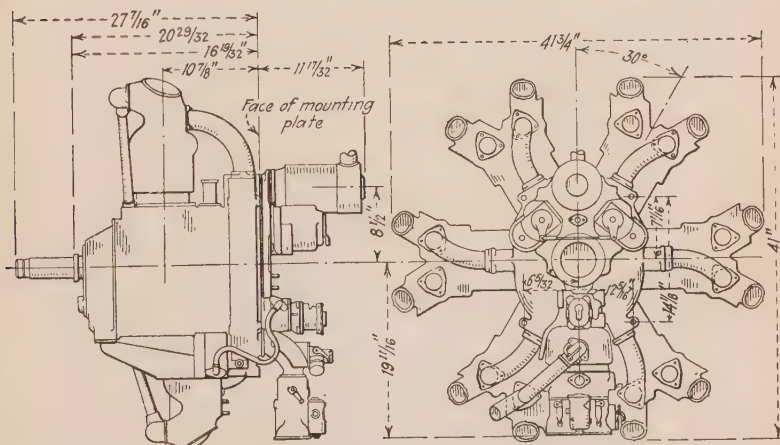


FIG. 10.—General dimensions of Challenger engine for use in installation.

tachometer, oil-pressure gage and oil thermometer are in proper operating condition. Turn the engine by hand, with the switch "Off," to be sure that everything is free.

If the engine has been in storage or idle for a considerable period, about a tablespoonful of cylinder oil should be injected into each cylinder and the engine turned over several times, with the switch "Off," before starting. This will insure the proper lubrication of the cylinder walls. **Turn the shaft over at least 20 times.** Have the throttle wide open and no fuel in the carbureters, and the switch Off.

Controls.—Set the spark lever at about two-thirds the travel from the full retard position for all **except hand starting**. For hand starting have the spark lever in the **full retard position**. The mixture control should be full rich, and the throttle closed tightly or barely "cracked"

open. Turn on the gasoline and prime the engine giving it 3 or 4 "shots" with the primer. **Be sure the primer connection shut-off cock is closed after the engine starts.**

Starting.—With the controls in proper position, crank the engine at least two full revolutions or in cold weather until the engine turns freely. As soon as the engine turns freely, however, stop cranking as additional mixture drawn into the cylinder tends to dilute the oil on the cylinder walls, thereby increasing the possibility of losing compression.

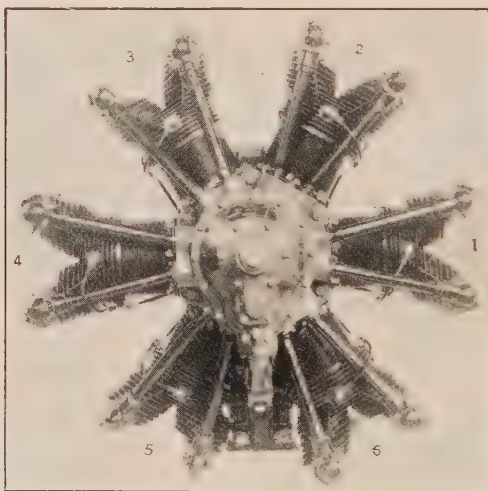


FIG. 11.—Guide for numbering cylinders.

With the throttle "cracked" or about one-tenth open, crank the engine over one cylinder, turn on the ignition switch, and operate the hand magneto as quickly as possible in order to take advantage of highest compression in a cylinder, making certain before this procedure that everyone and everything is clear of the propeller. When the engine starts, advance the spark immediately. When using an inertia starter, the starter should be brought up to speed with a hand crank taking approximately 45 seconds to reach between 75 and 100 r.p.m., on the hand crank. Do not attempt to get the starter up to speed too quickly as the amount of work necessary is much greater than if it is done

slowly. With the controls in the proper position, the propeller clear, and the switch turned on the Both position the starter can be engaged with the trip provided. If the engine does not start, the propeller should be turned forward by hand with the switch in the Off position in order to disengage the starter for a repetition of the above operations.

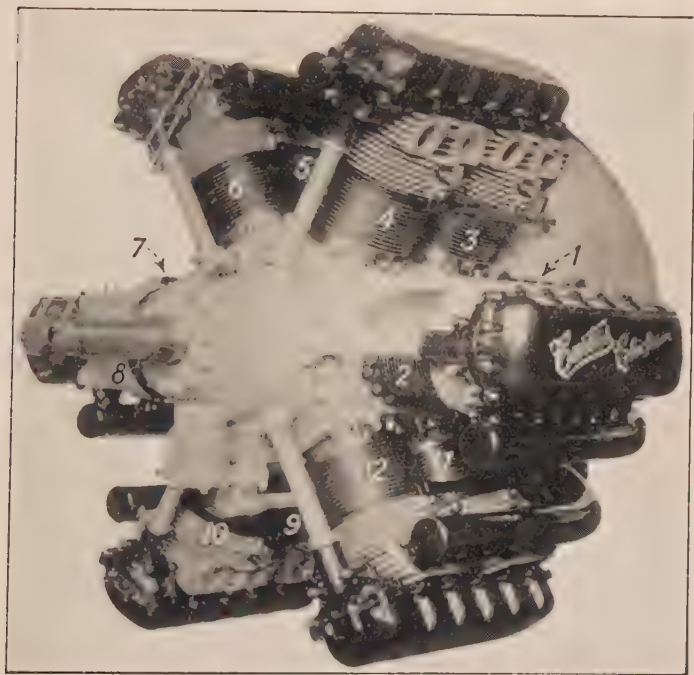


FIG. 12. Firing order of Chieftain engine. 1, 10, 5, 7, 4, 11, 8, 3, 12, 2, 9, 6, looking from propeller end toward pilot. The even numbers are the front cylinders.

When an electric inertia starter is provided the starter is brought up to speed by pressing the starter button until the pitch of the sound is steady; indicating that the flywheel in the starter has reached its maximum speed. The starter button is then pulled engaging the starter mechanism with the engine. With the controls properly set the engine

should start. Too much priming or too much mixture drawn into the cylinder with closed throttle causes such a rich mixture that the engine may not start. This will be indicated by no explosions or a feeble soft explosion.

When using an electric inertia starter the engine should be turned over a few times with the throttle wide open and the switch off, or turned backwards by hand (with the propeller) with the switch off. If there is evidence of too much priming or too much gasoline in the cylinders, indicated by poor compression and no starts, it is advisable in cold weather to inject a small quantity of hot oil through each spark plug in order to lubricate the cylinder walls thereby preventing scoring of pistons and cylinders. This is necessary only in extreme cases. **Always be sure that the primer supply line is shut off after starting.**

COMPLETE OVERHAUL

Crankshaft Assembly.—Remove the oil-retainer plugs from the crankpins and the anti-propeller end journal, taking care to identify each plug so that it can be replaced in the position from which it came.

Unscrew the plug in the propeller end of the crankshaft and then drive out what remains of the aluminum locking pin. Wash the inside of the shaft out with gasoline until it is clean and replace the plug in the shaft. Tighten it up to where it was before and put in a new aluminum locking pin. *Do not use anything but aluminum for the locking pin as the pin must be sheared off when removing the plug and a harder material will damage the threads.* Peen the lockpin hole in the shaft over just enough to stop the pin from getting out of the hole.

Clean the shaft thoroughly with gasoline, using a spray if available, then dry it, and if the shaft is not to be used right away be sure to cover it fully with some light rust-proofing compound such as light grade Corol compound.

The ball bearings which form main bearings should be tested to see if they run freely and quietly. Put a drop or two of light oil in the outer race before spinning each bearing. A serviceable bearing should spin easily and quietly. If there is more than 0.025 inch end play in the bearing, the bearing should be replaced by a new one.

There is a bearing at the anti-propeller end that does not carry any load but serves merely to pass oil into the crankshaft.

Assemble the oil-retaining plugs back in the positions from which they came. Be sure all cotter pins are in place tight enough to prevent them from moving.

Crankcase Assembly.—Each section of the crankcase should be cleaned and dried. Look the castings over carefully for cracks, especially at studs.

Measure up the shafts of the idler gear and magneto drive gears. Compare their diameters with the diameters of their respective bushings. The clearance of the idler gear shaft in its bushing should not be greater than 0.006 inch and that of the magneto gear shafts not more than 0.005 inch. If any of the clearances are greater renew the bushing or bushings and cut them to give from 0.001 to 0.003 inch for the magneto gear shafts and 0.001 to 0.003 inch for the idler gear shaft.

If it is necessary to replace any of the bushings remove the bushing being careful to avoid losing the locking pin. Drive new bushings in place and put the lockpins in the holes. Then peen the holes over enough to keep the pins in place. All cutting of bushings should be done on a grinder using a jig that may be obtained from the Curtiss Company, for locating the holes correctly. Follow the same procedure for the oil pump idler gear bushing. Its clearance should be the same as for the magneto gear bushings.

When all the bushings are correct, clean the case up thoroughly and dry. Be sure all grit is cleaned out of the case, especially where it could mix with the oil.

The crankshaft can then be placed in position in the antipropeller end bearing (with the crankshaft in a vertical position) and the propeller end section slipped on over the shaft into place. Then tighten the two parts together pulling all the nuts up a little at a time so that there will be no danger of springing the case.

Next, the spacer should be assembled on the shaft. Measurements should be taken of the bearing surface on which the cam assembly runs. These measurements (diameters) should be taken at right angles and at both ends of the spacer. At least four measurements should be taken.

Compare these measurements with the bore of the bronze bushing of the cam assembly. If the dimensions show a clearance of not more than 0.006 inch and both rubbing surfaces are in good condition, oil the bushing and assemble the cam assembly on the spacer. Then assemble the shim and gear in place on the shaft.

The remaining gears of the cam drive should next be assembled in the nose piece. Inspect the bronze bushing to see whether it is smooth and not over 1.003 inch diameter. The adjusting shaft has a large integral gear.

If the clearance of the adjusting shaft shows that the bushing should be replaced, the bushing should be pressed out. **Be careful to avoid losing the locking pin for the bushing.** The new bushing should be pressed in. The hole in the bushing for the locking pin must line up with the hole in the nosepiece so the lockpin can be put in place. Tap the pin in place and then peen over the edge of the hole so that the pin cannot work out.

The bushing can then be ground using a fixture similar to that used at this plant. This fixture must be used to make the adjusting shaft line up properly when in place in the bushing. The bushing should be cut to 0.999 inch to 1.000 inch diameter.

Remove the oil-pressure relief valve and clean all oil passages in the nosepiece, then replace the relief valve.

Oil the adjusting shaft and assemble it in the bushing. The drive shaft assembly should be assembled into the adjusting shaft and locked in place by its nut and washer.

The next step is to assemble the nosepiece on the engine. Be careful in placing the gasket on over the studs to avoid tearing it. To make sure that there is backlash in the gears of the timing train, tighten the nut which holds the timing disc in engagement and then try to turn the nut with the fingers. If the nut and the shaft, to which it is attached, can be "rocked" enough for the mechanic to feel a slight motion the gears have backlash enough.

The flat deflector should be put in place on the shaft and then the propeller thrust bearing put in place. Next, the "dished" oil deflector is assembled with the flat surface next to the thrust bearing, the whole being locked in place on the shaft by the locknut. **Be sure to get the latter on tight enough so it cannot loosen.**

The cover plate should not be assembled until after the engine has been timed.

The engine will then be ready for assembling the camfollower guides and camfollowers.

The camfollowers should be cleaned up thoroughly and inspected for wear. Pay particular attention to the condition of the rollers and

the roller pins. The rollers should be free to turn but not free enough to have "wobble" on the pins. Note the edges of the rollers to see whether or not they are chipped. If any are chipped replace the whole camfollower. If the camfollowers and guides are in good condition oil them with cylinder oil and assemble on the engine.

Connecting-rod Assemblies.—The master-rod bearing should be measured and compared with its corresponding crankpin diameter. If the average diametrical clearance is not more than 0.005 inch and the bearing material has a good appearance, **do not disturb the bearing.** If the bearings need replacing, the old shells may be removed by cutting off the "headed over" portion of the rivets and driving the rivets out. New shells should be riveted in place. **Be sure the rivets are tight.** The "pinch" or "draw" of the shells in the rod should be from 0.007 to 0.009 inch to insure their seating tightly in the rod.

The "draw" may be fitted as follows: File the parting of the shells until the shells hold the cap and rod apart from 0.007 to 0.009 inch when the cap is held by hand in its place on the rod. When the cap is tightened up the shells are forced to seat tightly in the rod. The cap should be tightened in place preparatory to boring the bearing.

The rod should be put into a fixture and the bearing finished by a fly cutter boring bar to a diameter which will give a clearance of 0.002 to 0.0025 inch. The edges of the bearing should be chamfered and the burr formed on the edges of the oil grooves should be removed.

Check the fit of the wristpins in the master-rod bushings and the short-rod bushings. There should not be more than 0.003 inch clearance at these bushings.

If it is necessary to renew the wristpin bushings in the master rod, press the oil bushings out and drive new bushings in their place. These bushings should be ground to give 0.0000 to 0.001 inch clearance on the wristpin. Use a Curtiss jig. The use of this jig will insure the correct alignment of the holes.

The wristpin bushings in the short rods may be easily removed and replaced on a small arbor press, as may the piston-pin bushings. When cutting the piston-pin bushing of the master rod, the rod should be held in the same jig.

When the master and short rods are ready to put back in the engine, oil all the bearing surfaces and assemble short rods 3 and 5 on master rod cap 1. Have plenty of oil on the crankpin. Put the assembly in

through the hole in the crank-case for cylinder 5, hold the cap in place on the crankpin and put the master rod in place through the hole for cylinder 1. Be very careful to avoid "nicking" or scratching the crankpins. Put the nuts on and draw the cap and rod together gradually. Tighten the nuts and try rotating the rod on the crankpin. If it turns freely, cotter pin the nuts. Follow the same procedure for master rod 4, putting the cap and short rods in place through the hole for cylinder 5.

When the rods are assembled on the crankshaft, the etched numbers on each rod should be toward the propeller.

Pistons, Piston Rings, and Piston Pins.—Clean the pistons up thoroughly and remove all the rings. *Tag each ring so it can be returned to the same groove in the same piston.* Look at all the lands to make sure none are cracked or broken.

Any carbon which may be in the ring grooves should be removed. Be careful not to scratch the fillets or the bottom of the groove.

Examine the pistons closely for cracks. Measure up the piston at the piston ring lands and the bottom of the skirt. Do not measure the piston skirt parallel to the piston-pin hole as each piston has an eccentric relief cut from the fourth ring groove to the bottom of the skirt. Record the measurements.

Try the fit of the piston pin in the piston as the pin should be an easy hand-push fit. If the pin is tight it is probably because carbon has formed in the piston bosses and a thorough cleaning will free the pin. Only one of the piston-pin locking rings need be removed to remove the piston pin.

Measure the piston pins. If any are out of round more than 0.003 inch or show signs of overheating, replace them.

Measure the piston ring gaps, holding the rings in a ring gage. If any scarf-joint compression rings have gaps more than 0.040 inch they should be replaced by others. If any scarf-joint oil control rings have gaps more than 0.035 inch they too should be replaced. Any engines that have step-joint rings should have these removed and scarf-joint rings put in their places.

Make sure no rings are cracked or broken.

Reassemble the rings on the pistons.

Cylinder Assemblies.—The cylinders should be inspected thoroughly after the combustion chamber has been cleaned. Watch the head closely for cracks and the barrel for spots or streaks indicating heavy

rubbing. Test the valves with gasoline and if they do not leak do not grind them. They should be removed from the cylinder head so that the seats may be inspected. Unless any valve looks as if it needed a slight touching up do not grind it.

If the bronze valve seats appear pitted but the valves do not leak, do not recut them as this pitted appearance is characteristic of the aluminum bronze seats after the engine has been used for a short time. If the valve seat is pitted, and the valve leaks, try lapping the valve in and if a short grinding does not stop the leaking, reface the seat. Do not cut any more than is absolutely necessary off the seat, and then touch the valve up using grinding compound.

Measure the cylinders to determine the piston clearances. If the cylinder is not more than 0.005 inch out of round or the clearance is not greater than 0.050 inch at the top of the piston and 0.042 inch at the bottom the cylinder and piston need not be replaced. Practically all wear takes place on the piston. Reassemble the valves in the cylinder head. **Be sure to put the safety-lock ring on each valve stem.** Put the valve spring back on the valves and lock the split bushing holding the valve spring washer in place. The bushing should be screwed down until the locking pin is just flush with the top of the valve spring washer. **Put the lockpin in with the bent portion pointing UP, not down.**

After cleaning and inspecting the rocker arms and their bearings assemble them on the cylinder.

It is well to overhaul cylinders 1 and 4 first.

As soon as a cylinder is ready to assemble on the engine, oil the piston pin and put the piston for that cylinder on its connecting rod. **Each piston should be assembled in the engine so that the piston boss which has the number stamped on it is next to the propeller.**

Be sure BOTH piston pin locking rings are tight in place in EACH piston.

Compress the rings in place with the brass clamp furnished with the tool kit, oil the cylinder walls, and slip the cylinder on over the piston. Cylinder 1 should be assembled first. Put each cylinder on and tighten all the nuts down tight. A gasket compound such as "Heldite" should be put on the flange and crankcase. Make sure all the hold down nuts are tight on each cylinder.

Next, assemble the intake pipes. Put the clamp ring and rubber packing on the intake pipe and assemble the pipe on the engine. Tighten and lock the cap screws holding the pipe to the cylinder before

tightening the rubber packing and its gland in place. **Do not attempt to pull the packing gland down enough to seat on the crankcase casting as it is not supposed to be drawn down so far.**

Push Rods and Push-rod Housings.—All push rods should be tested for straightness. Use an indicator and "V" blocks. Rotate each rod in the V blocks taking an indicator reading at the center. If the indicator shows a "bow" of more than 0.006 inches, straighten the rod. All push rods are etched according to the cylinder they are used on.

The packing gland on the rocker-arm housing should be loosened so the push-rod housing tube can be moved in and out of the rocker-arm housing. Put the push rod in its proper housing and assemble all on the engine. There should be some oil on each ball end of the rod. It will be necessary to loosen the adjusting screw as much as possible and open the valve somewhat in order to get the push rod in place. It is advisable to use new gaskets under the lower end of the push-rod housings and between the rocker-arm housing and the cylinder head during each overhaul. Fasten the housings to the engine and tighten the tappet adjusting screws to give 0.005 inch clearance for the intake valves and 0.010 inch for the exhaust valves. **Be sure to tighten the locking screws.**

Accessory Drive.—Assemble the crankshaft gear into the crankshaft making sure the etched splines mesh. Cotter the nut holding the gear in place. **Be sure the cotter is tight.** Turn the crankshaft in the direction of rotation until the etched gear tooth reaches a position of about 36 degrees before the vertical. The magneto-drive idler gear has three sets of two marked teeth, two sets diametrically opposite and the other halfway between the two. This latter set should mesh with the marked tooth of the crankshaft. Then mesh the left magneto drive gear with the idler gear, lining up the etched teeth. Do the same with the right magneto drive gear. Assemble the oil pump drive idler gear.

Put the cover in place over the gears, using a new gasket. Check the backlash of the gears. It should be 0.003 to 0.010 inch.

Disassemble the oil pump for inspection. The dural follower gears probably will be scored as will the pump bodies. This scoring is characteristic and unless very deep will not affect the operation of the pump. Clean out all pump passages including the relief valve chamber. Reassemble the pump *dry* and test it by spinning the shaft with the fingers. If it turns freely put some oil into both pumps and assemble the pumps on the engine. If the keys of the shaft and keyways of the

pump bodies are in line and the pump is held with the gear down, it is possible for the pump shaft to drop out. **Take care that this does not happen.**

Assemble either the fuel pump or the substituting cover, whichever the engine has.

Assemble the tachometer drive adapter after oiling it.

The oil strainers and oil pump should be cleaned thoroughly. Reassemble the strainers in the sump and fasten the sump in place. Connect up the oil pressure line.

Put on the generator substituting cover.

Magnetos.—If the magnetos have given indications that they need repair have them overhauled by a magneto specialist.

The engine is then ready for timing.

The magnetos should be timed before the valves.

Remove the plug in the crankcase just ahead of cylinder No.1 and turn the crankshaft in the direction of rotation until the line marked "IGN. 1" lines up with the line on the side of the hole. On some engines the line marked "EX. OPENS 5" coincides with the line marked "IGN. 1." Turning to the line marked "IGN. 1" puts the crankpin of cylinder 1, 36 degrees beyond top center, and in the correct position for timing the **magnetos**, the magnetos being timed on cylinder 1 and the valves on cylinder 5. The line on the counterweight, lines up with the line in the hole when piston 1 is in firing position and where both lines coincide; also when piston 5 is 96 degrees beyond bottom center, the point where the exhaust valve of cylinder 5 starts to open. Some engines will probably have separate lines for timing the magnetos and the valves.

Magneto and Valve Timing.—If the magneto-drive coupling has not been removed from the magneto shaft, the shaft can be turned until the distributor gear marks line up with the marks on the frame, then mesh the coupling with the magneto drive gear coupling. Tighten the magneto mounting nuts enough to provide friction so the magneto can be turned by tapping it with the hand.

Tap the magneto to a retard position. If "feelers" are to be used for setting the magneto, separate the breaker points and insert a 0.0015 or 0.002 inch thickness gage or "feeler." Tap the magneto in the direction opposite to the rotation of the shaft until the points barely release the feeler. Tighten the magneto in this position. Then rotate

the crankshaft backwards about 20 degrees, and put the feeler between the points again. Turn the crankshaft in the direction of rotation until the feeler is released. See if the line on the counterweight and the line on the hole line up. If they do not, shift the magneto to make them line up when the points start to separate. Repeat with the other magneto. *Each magneto should be replaced in the same position on the engine it was in before the overhaul.* **Be sure the spark advance lever of the magneto is in the full advance position when timing.**

If a small light is to be used in timing, put a piece of insulating material between the bronze arm carrying the breaker points and the springs making contact with this arm. Connect the light, battery, and breaker points in series. Time the magnetos as described before, moving the magneto until the light goes out instead of the release of the feelers.

If the magneto couplings have been disturbed, remove the couplings and keep trying them in different positions on the magneto shaft until a position is found where the magneto can be timed by the method described before.

Assemble the ignition cable assembly on the engine but leave the distributor blocks off one magneto.

To time the valves leave the crankshaft in position for cylinder 1 to fire, if there is but one mark on the center weight, that is, with the magneto distributor gear marks lined up, and the line on the counterweight lined up with the line in the hole. If there are two timing marks, turn the crankshaft backwards past the other mark enough to take the backlash from the gears and then turn it forward to the valve timing mark.

Loosen the nut of the adjusting shaft about two turns and push the nut in enough to free the serrated timing disc. Using the wrench, turn the timing gear shaft (put wrench in hole to engage pin) until the *exhaust* valve of cylinder 5 just starts to open. Tighten the nut.

Turn the crankshaft backwards about 20 degrees and then move it forward slowly until the exhaust valve of cylinder 5 just starts to open. See if the line on the counterweight and the line in the hole match up. If not, time the engine again. Cotter pin the nut and put on the thrust-bearing cover.

Put the spark plugs in the cylinders. Tighten them in place so that they will not loosen. The spark plug gaps should be 0.015 inch for B. G. and A.C. (A.C. dot) plugs. All plugs should be clean both inside and out. Connect the spark plug wires.

Put on the rocker-box covers.

Pour about 2 quarts of oil into the gearcase through the hole in the starter deck and put on the starter or starter substituting cover.

The carbureter should be inspected before being replaced.

Fasten the carbureter spacer and carbureter in place. Connect up the exhaust heating equipment for the carbureter. *This heating equipment should not be altered in any way. The valve in the elbow at the carbureter spacer should be fully open in cold weather and nearly closed in hot weather. For other temperature conditions the valve should be between these positions.*

CHAPTER 3

THE WASP AND HORNET ENGINES

The Wasp and Hornet engines are manufactured by the Pratt and Whitney Aircraft Company of Hartford, Conn., to whom we are indebted for the following information regarding their proper maintenance. These engines were first used in large quantities by the United States Government in army and navy airplanes and are now being extensively used in commercial transport service. The Wasp is shown in Figs. 1 and 2.

Both the Wasp and Hornet engines are radial, nine-cylinder air-cooled. They are alike except in size. The main dimensions are as follows:

Commercial rating at 1,900 r.p.m.	Wasp 400	Hornet 500
Cylinders.....	5.75 × 5.75 inches	6.125 × 6.375 inches
Compression ratio.....	5.25:1	5:1
Piston displacement.....	1,344 cubic inches	1,690 cubic inches
Outside diameter.....	50 $\frac{5}{8}$ inches	54 $\frac{1}{2}$ inches
Mounting bolt circle.....	22 $\frac{3}{8}$ inches	22 $\frac{3}{8}$ inches
Total length.....	43 $\frac{3}{8}$ inches	44 $\frac{5}{8}$ inches
Length back of mounting...	14 $\frac{1}{4}$ inches	14 $\frac{1}{4}$ inches
Distance from mounting to C. L. of propeller.....	23 $\frac{7}{16}$ inches	25 $1\frac{1}{16}$ inches

The unique features of this engine are its solid master connecting rod and two-piece crankshaft, the forged-aluminum crankcase, enclosed valve gear, built-in supercharger, and the grouping of all accessories at the rear. These major features combined with painstaking manu-

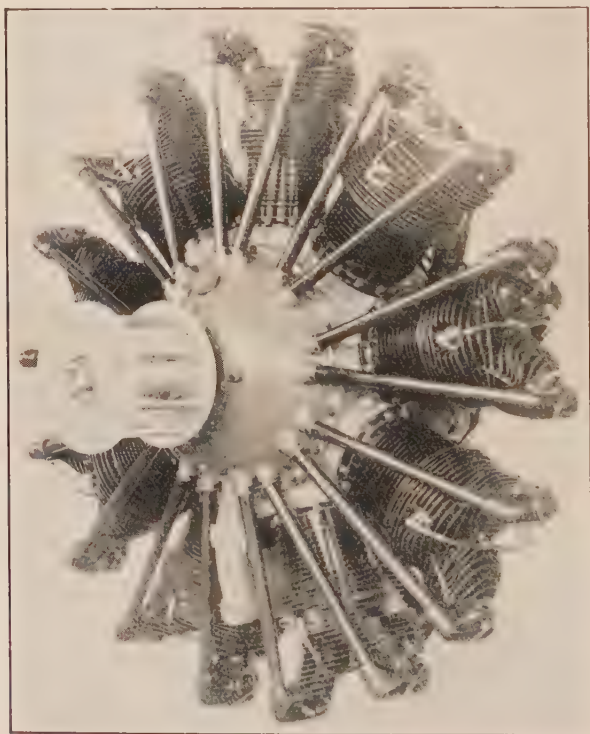


FIG. 1.—Front end of Pratt and Whitney "Wasp."

facture make possible the Wasp's dependability and a high performance for the airplane with which it is equipped.

Crankcase.—The *main* crankcase is divided into two similar sections in the plane of the cylinders and united by nine through bolts between the cylinders as well as by the cylinder flanges. With this construc-

tion, the explosion forces are equally distributed between the two main bearings, one of which is carried in each section of the case.

The *nose*, or front section of the case, is hemispherical in shape. It carries a deep-row ball bearing which transmits the thrust of the pro-

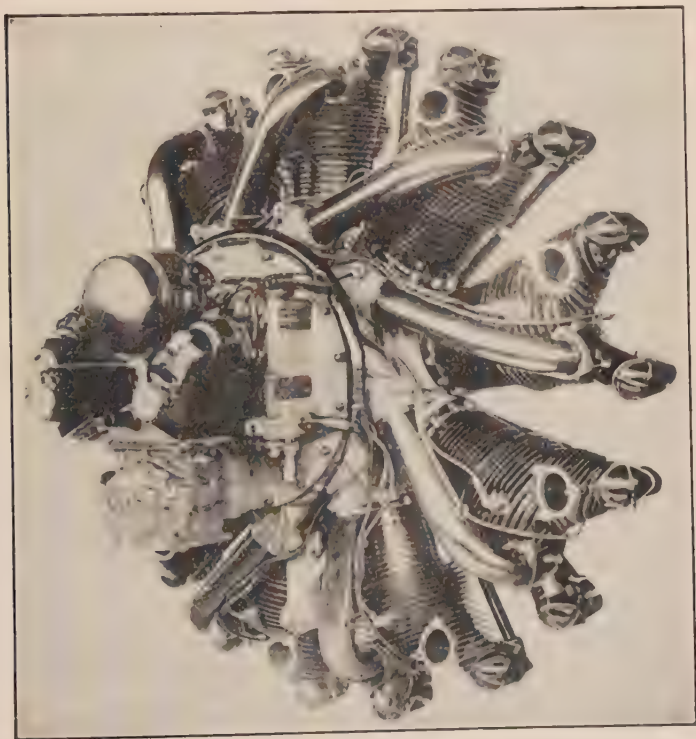


FIG. 2.—Back end of "Wasp" engine.

peller from the shaft to the engine mounting via the crankcase. The valve tappets are also carried in this section, which encloses the cams and their operating mechanism.

The *blower* or mounting section supports the engine in the airplane and is attached to the rear of the main case. The supercharger is carried in this section, together with its gearing. The mixture is fed into an

annulus from the impeller and thence to the cylinders by means of tangential pipes. The *rear* or accessory section of the case is attached to the blower section. It carries all the accessories, including two Scintilla magnetos, momentum starter, fuel pump, double Stromberg carbureter, oil pumps, strainer, and relief valve, tachometer drive, and two synchronizer drives. Provision is also made for mounting and driving a generator. The blower and rear sections of the case form an assembly and may be removed from the main case as a unit, without disturbing any of the accessories or their gearing. Likewise, the main and nose sections may be removed as a unit with the cylinders in place, leaving the blower and rear sections in the airplane.

Crankshaft.—The single-throw, two-piece crankshaft is supported on three roller or ball bearings. There is one on each side of the crankpin, and the third, just behind the propeller hub, takes the propeller thrust as well as radial load. To assemble the single-piece master rod, the shaft is divided into a forward and rear section, as in Fig. 3. The crankpin is integral with the forward section, which transmits the power to the propeller hub carried by it. The rear section telescopes into the crankpin and is carried completely through it. The two sections are united by a through bolt and kept in the proper angular relation by splines.

Connecting Rods.—The master connecting rod has a solid instead of detachable-cap big end. This construction makes possible high crank speeds which have been impossible with the two-piece rod. Babbitt-lined, big-end bushings are inserted in the rod and bear directly on the crankpin. Eight I-section link rods are attached to the master rod by means of knuckle pins. Each rod is bronze bushed for the piston and knuckle pins. Oil is carried under pressure to the big-end bearing and also the knuckle pins.

Cylinders.—The cylinder barrels have integral fins and are machined from steel forgings. Each barrel is screwed and shrunk into a cast-aluminum cylinder head. This is a permanent joint and cannot be disassembled. Each cylinder has one inlet and one exhaust valve, seating on inserts which are shrunk into the head casting.

The proper cooling of the exhaust-valve seat and stem is of great importance, especially in an air-cooled engine. The Pratt and Whitney engine has the valve gear housed in extensions cast on the cylinder head. These parts form additional radiating surface, and the one on the exhaust

side is provided with cooling fins. As a result of this construction, valve grinding is not necessary oftener than every 200 to 300 hours of service.

Valve Mechanism.—All valve-operating parts are enclosed. The rocker arms are supported by ball bearings in the rocker housings which are part of the cylinder head. The 18 tappets are located in the front section of the crankcase and actuate the rocker arms through tubular

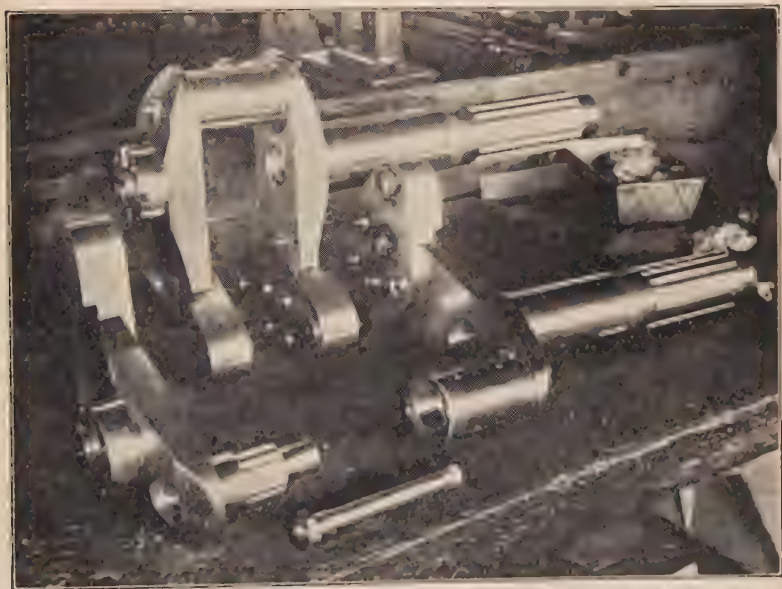


FIG. 3. Crankshaft of Wasp engine. The one in front shows how it is made in two parts that fit together with splines and are held by a through bolt.

duralumin push rods which have hardened-steel ball ends. These rods are enclosed by telescopic covers held in place by springs. The cover tubes can be collapsed by hand, and bayonet locks are provided to retain them in this condition while they are being removed. Each rocker housing has a removable cover held in place by a spring ball. These covers and the push-rod covers and push rods can be removed without special tools.

Two concentric valve springs are used, secured to the valve stem by a split cone and washer. Inlet- and exhaust-valve springs are interchangeable. The valve springs can be removed without taking out the rocker arms. After the push rod is taken out, the rocker arm can be tipped up far enough to allow the valve springs to pass. The valve-clearance adjusting screw is in the end of the rocker arm over the valve. A half ball is used between the adjusting screw and the valve stem to minimize friction at this point.

Timing Gear.—The cams, which actuate all the valves, run on a sleeve on the crankshaft. A train of spur and internal gears drive the cams at one-eighth crankshaft speed in the opposite direction to the crankshaft rotation. The cam-drive gear on the crankshaft is not keyed to the crankshaft but to the sleeve on which the cam itself rotates. The front end of this sleeve has a large number of serrations which mesh with similar serrations on the rear end of a sleeve which carries the propeller thrust bearing. These two sets of teeth are normally held tightly together by the thrust-bearing nut. When the engine is being timed, however, this nut is slacked off, the two sleeves are slightly separated, and the cam can then be turned by a special wrench which has teeth to engage with one of the cam-drive gears. After the adjustment is made, it is locked by screwing up the propeller thrust-bearing nut.

Accessory Drives.—The accessories are driven by three lay shafts which extend entirely through the blower and rear sections. Each shaft carries a spur gear at its forward end, which engages with a gear attached to the rear of the crankshaft. The upper shaft provides a drive for the momentum starter and a generator, if used. Each of the two lower shafts drives a magneto at its rear end, through a readily adjustable coupling. Besides this, two vertical drives are provided for by a bevel gear on each shaft. The upper drive is for the synchronizer heads and tachometer, while the lower drives an oil pump on the right side and a fuel pump on the left.

The supercharger impeller shaft is in line with the crankshaft and driven from it at high speed by two pairs of spur gears.

Lubricating System.—The oil-pump assembly consists of two gear pumps, one supplying oil under pressure to the engine bearings, and the other for scavenging. Oil is taken from the tank by the pressure pump, and after passing through a strainer located just forward of the

carbureter is carried through the blower section, down into the sump, and thence up into the hub of the cam drum in the nose of the engine where it is fed into the crankshaft. A relief valve to regulate the oil pressure is located beyond the oil screen just off the strainer chamber. The

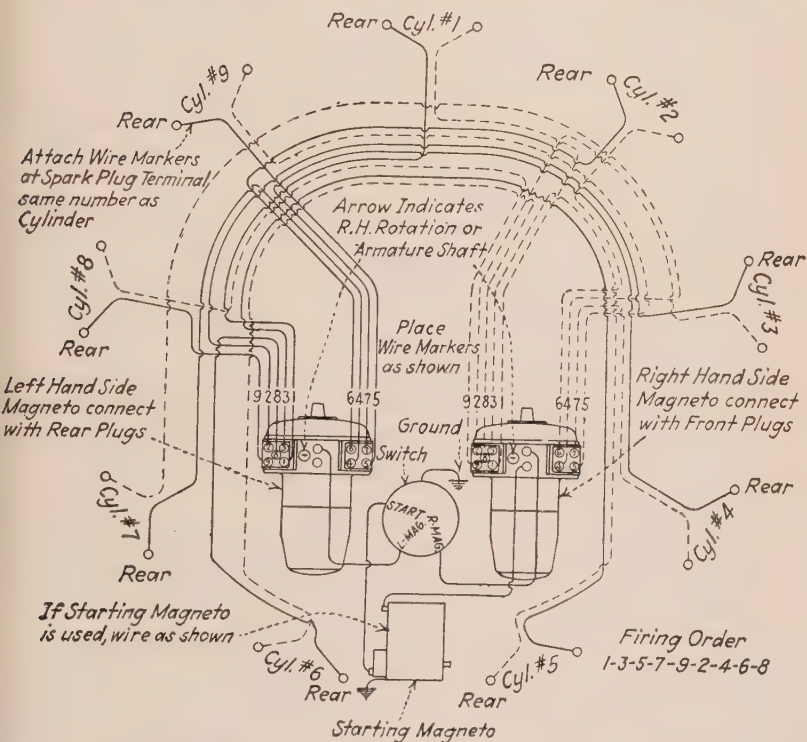


FIG. 4.—Wiring diagram Wasp engine looking at magneto end.

crankpin bearing, knuckle pins, cam drum, cam-drum pinion shaft, accessory shafts, and the supercharger gearing are all lubricated by oil under pressure. Oil is taken from the strainer chamber by drilled passages to lubricate the accessory drives. All the other engine parts are provided for by the mist or spray from the pressure-oiled parts, except the rocker arms and the magnetos. The felt reservoirs in each rocker

bearing must be replenished manually. All the oil drains into a sump carried between the cylinders 5 and 6, from which it is returned to the oil tank by the scavenging pump. The discharge or warm oil is carried in a jacket around the carbureter elbow to prevent the throttle freezing.

Intake System.—Fuel is supplied to a double Stromberg carbureter by a C-5 fuel pump, which is equipped with both a pressure-regulating valve and a bypass valve for the hand pump. The mixture is taken from the carbureter and delivered to the cylinders by means of a General Electric centrifugal supercharger, the impeller of which, in normal operation, runs approximately 10,000 r.p.m. The fuel pump, carbureter, and supercharger are located at the rear of the engine. A mixture control is provided which is effective to 25,000 feet.

Ignition.—Ignition is furnished by two nine-cylinder Scintilla magnetos located at the rear of the engine, each firing spark plugs in all nine cylinders, thus giving two independent sources of ignition. A Splitdorf hand-booster magneto is furnished for starting ignition. The wiring diagram is shown in Fig. 4.

Starting.—An Eclipse momentum starter is furnished with each engine. Energy is stored in a small flywheel running at high speed which furnishes power to start the engine. This equipment is capable of turning the propeller from four to six complete revolutions on one winding.

Equipment.—Each engine is completely equipped and ready to run. The equipment includes a Stromberg carbureter, two Scintilla magnetos, an Eclipse momentum starter, a C-5 fuel pump, and a Standard Steel propeller hub. Each engine is shipped in a substantial wooden box, together with a complete set of tools and an instruction book.

INSTALLATION

Unpacking.—The Wasp engine is packed for shipping with the crankshaft in a vertical position. The upper part of the shipping box is merely a cover and is held in place by woodscrews passing through the iron lifting straps. One screw in each strap is covered by a seal, and these must be removed before the screw can be taken out. Lifting off the cover will then expose the engine.

A quantity of oil is put in each cylinder before the engine is shipped. While the cylinders are in the horizontal position, remove the spark

plugs from the underside of the cylinders and turn the crankshaft around two or three times to clear out the surplus oil. Clean the plugs and replace them.

Lifting.—Two lifting eyes are provided on the engine crankcase. These are located at either side of the top of cylinder 1. A lifting yoke or sling should be provided to hook into these eyes, having a spreader so arranged that the lifting ropes or rods will not touch the cylinders or other engine parts. After removing the box cover, the box can be turned on its side so that the engine is in an upright position.

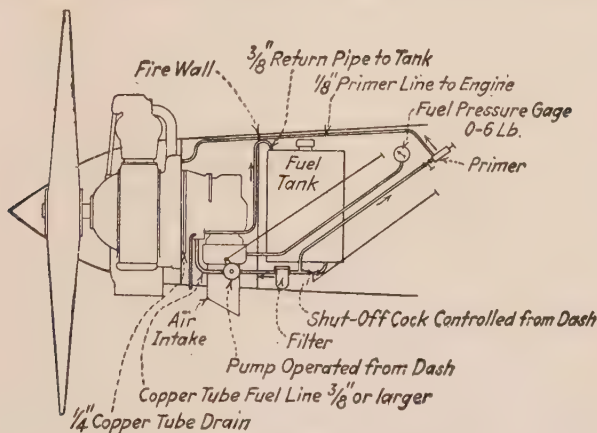


FIG. 5.—Installation diagram of Wasp engine.

Caution: Do not let the box tip over. The sling can be attached and the weight of the engine taken up by the hoisting rope as the box is being turned.

Take out the bolts which attach the square steel mounting plate to the box rather than the ones which attach the engine to the plate. The box can then be slid away toward the rear, taking care not to damage pipes or other parts of the engine. After this, the steel plate can be removed from the engine.

Mounting.—The engine is held in place on the supporting flange by nine $\frac{7}{16}$ inch bolts. These will be $3\frac{1}{4}$ inches long in the average case and should be provided with castellated nuts, washers, and cotter pins. Figure 5 shows engine installation and connections.

When putting the engine in position, the nose may have to be tipped down at an angle in order to pass the carbureter through the hole in the mounting flange. When doing this, particular care should be taken not to strike the magneto or other fragile parts.

Fuel Supply.—The carbureter is a Stromberg, Type NAY-7A. Type C-5 fuel pump is used. One-half-inch diameter tubing is recommended for all fuel connections, and in no case should smaller than $\frac{3}{8}$ -inch diameter tubing be used except for the safety drain from the fuel-pump gland. The latter is $\frac{1}{4}$ inch and must be carried down and out of the cowlings without sharp bends and traps and be cut off square. The piping required includes a supply pipe from the main tank to the fuel pump and a return pipe from the fuel pump back to the tank (see piping diagram). A pipe from the fuel pump to the carbureter is supplied. There is a $\frac{1}{8}$ -inch pipe tap in the carbureter which can be used for connecting to the fuel-pressure gage. A 6-pound gage should be used. A strainer is incorporated in the carbureter, and all fuel should also be strained when filling the tank.

The primer furnished with each engine can be mounted on the instrument board or near the starting crank and connected to the primer piping which is already on the engine. The fuel supply for the primer can be taken from any convenient point, preferably at the lowest place in the line but certainly where fuel is always available.

A shut-off cock must be included in the primer-supply line at the primer pump, to prevent fuel from entering the engine through the primer system except when priming.

Oiling System.—The oil should be located near the engine and, if possible, slightly above the center of the engine; a large head, however, is not desirable, since it may cause oil to leak through the pump when standing for a long time and fill the engine. In designing the oil tank, figure on an average oil consumption of $1\frac{1}{2}$ gallons per hour.

The filler should be at least 2 inches in diameter and must be located so as to insure an air space above the oil equal to at least 10 per cent of the volume of the oil.

A $\frac{3}{4}$ -inch vent should be provided in the top of the tank. If this can be arranged so that oil will not issue from it when the plane is being maneuvered, the vent pipe can be carried down and out of the fuselage. Otherwise, this pipe should be connected to the engine crankcase. A

hole may be tapped in the generator hole cover plate just forward of and above the starter, for this purpose.

A large drain valve should be accessibly located under the oil tank.

The oil piping to and from the engine should be 1-inch seamless copper tubing and should have as few bends and connections as possible. Smaller piping will give trouble in cold weather when the oil is thick. See the oil-connection diagram for the proper hook-up.

The oil strainer is at the rear of the engine, just forward of the carbureter. Provision should be made in the cowl and structure to get at this readily. The oil-pressure relief valve is at the side of the strainer chamber and faces toward the rear and the left side and should be made accessible.

The oil-pressure gage connection is on the right side of the engine at the rear of the mounting flange and is tapped $\frac{1}{8}$ -inch pipe thread. Copper tubing $\frac{5}{16}$ inch O. D. should be used, with a pig tail at the engine, and a 150-pound gage. The oil-thermometer connection is also on the right-hand side and is in the oil-outlet passage. This is tapped $\frac{5}{8}$ inch, 18 threads. The thermometer should read in degrees Fahrenheit to 212°, or in degrees Centigrade to 100°.

Ignition.—Ignition is provided by two Scintilla magnetos, Model VAG-9D. Both magnetos have clockwise rotation, looking at the driving end. A Splitdorf hand-operated booster magneto is provided for starting and should be wired to the trailing-brush connection (marked H) on one of the main magnetos. The base or frame of the hand magneto must be grounded or connected to the engine crankcase in order to get the best results. A magneto switch is supplied and has a connection for grounding the starting magneto as well as the main magnetos. This must be connected as a safeguard against accidental starting. Seven-millimeter wire is used for high-tension connections. See the wiring diagram for the marking of the magnetos and switch.

Inspection Facilities.—The cowl forward of the firewall should be easily removable, and large inspection doors are desirable in each side cowl just forward of the firewall to give access to the magnetos, oil strainer, etc.

Controls.—The location and movements of the throttle, mixture control, and spark-timing control are shown on the installation drawing, Fig. 5.

Cowling.—In designing enclosures for the Wasp engine, the cylinder heads must be left exposed. Examination of a cylinder of the engine will show that the first ten cooling fins counting up from the crankcase are very thin. These fins are on the cylinder barrel. Above this point, the fins are thicker and are on the cylinder head. All of the thick fins must be exposed, and two or three of the thin ones, also. A certain amount of cooling is required for the crankcase, and for this purpose, forward-opening louvers should be provided in the front part of the cowl to take air in, and backward-opening louvers should be provided near the rear of the engine just in front of the firewall to let the hot air out. As many and as large holes as possible should be made in the mounting plate, to permit good air circulation.

Exhaust Pipes.—The exhaust-port flanges furnished with the engine are intended to be welded to 2½ inches O. D. No. 20 gage steel tubing.

Air Intake.—An air scoop is required. This should project through the under part of the cowling and be cut off at an angle of 30 degrees to the horizontal. It is desirable to run an exhaust pipe through this air horn or make some other provision for warming the air.

Tachometer Drive.—Two tachometer drives are provided, one on each side of the engine. Connections are threaded to take the standard swivel head so that the shafts can be brought off in any desired direction. The driving spindles rotate counter-clockwise, looking at the engine, and run at one-half crankshaft speed.

Starter.—Flywheel starter Model M-1932, of the Eclipse Machine Company is generally supplied, but others can be used. The starting crank is detachable and requires an outboard support or bearing where it passes through the cowling. The location of this support is shown on the installation drawing. A rigid rod to pull the starter trigger should be carried to the cockpit. This has to be pushed to disengage the starter, if a start is not accomplished.

Attaching Propeller.—The propeller should be carefully checked for balance and tracked before being placed on the engine. The crankshaft splines and thread should be lightly oiled before the hub is placed on the engine. Excessive oiling will only result in oiling the cowling, etc. The propeller-hub nut should be screwed up solid but should not be forced with a heavy sledge. Recheck the track after attaching the propeller to the engine. The hub can be removed by backing off the same nut used to hold it in place, no other puller being required. Be

sure that the propeller-hub nut is locked with a $\frac{3}{16}$ -inch diameter by $3\frac{1}{2}$ -inch long cotter pin which extends completely through hub and nut.

This propeller should be of such design as to hold the engine speed down to approximately 1,900 r.p.m. in level flight.

OPERATION

Starting.—Retard the spark, set the mixture control full rich, crack the throttle slightly open, and turn the ignition switch to the “on” position. Make sure that the fuel supply is turned on and pressure pumped up with the hand pump to at least 3 pounds. Insert the starting crank and wind up the starter. There is little danger of cranking the starter too fast. Enough energy should be stored up to crank the engine at least two or three complete revolutions. This takes about a minute, and the starter speed necessary will be learned after one or two trials. When starting stone cold, prime the engine with three or four complete strokes of the priming pump. Pull the primer plunger back slowly to obtain a full charge and push it in rapidly to atomize the fuel. When the starter has been wound up, quickly buzz the hand magneto and pull the starter trigger. If everything is in good condition, the engine should start immediately, even in cold weather. As soon as the engine starts, advance the spark.

When the engine is warm, two or three strokes of the primer will be enough. *If the engine does not start immediately, do not keep on priming but find out what is wrong. Excessive priming washes the oil from the cylinder walls and is very likely to cause scoring of the pistons and cylinders.* The primer fuel supply should be shut off as soon as the engine starts.

If the engine fails to start, check to see whether the switch is on, the throttle is just cracked open, the mixture control is set full rich, and there is actually fuel at the carbureter and at the primer; also, that the starting magneto gives a good spark at the running magneto.

If the starter runs down before the engine starts, the starter jaw will be left in engagement. Before the starter can be rewound, it is necessary to disengage the jaw, either by pushing in the starter trigger or by turning the propeller forward a short distance.

Hard Starting.—An engine in good condition should start promptly, regardless of the air temperature, providing the above instructions are

carefully followed. Hard starting is often found to be caused by leaky primer lines or primer pump packing. All primer connections should be kept tight, and the pump packing properly adjusted. In some installations, it is necessary to operate the wobble or hand pump while priming, as otherwise the primer may not receive any fuel. Another frequent cause of hard starting is that a strong spark does not reach the running magnetos from the starting magneto. This can be readily checked by removing the high-tension lead from the hand-starting magneto and trying it on the engine, at the same time turning the starting-magneto crank. The spark should jump from $\frac{1}{4}$ to $\frac{3}{8}$ inch without difficulty. If it does not, it is likely that the insulation on the high-tension wire has been damaged or that a proper ground has not been provided between the hand-starting magneto and the engine.

Ground Test.—After starting, run the engine slowly, in order to warm it up gradually, until the oil temperature has reached 100° F. or 40° C. After the oil has been warmed up, the engine should be gradually brought up to full throttle. Before doing this, be sure the wheels are properly blocked and the stick pulled back. With the throttle wide open, try both magnetos with the switch, observe whether the fuel pressure is between 3 and 4 pounds and the oil pressure from 75 to 100 pounds, also the propeller speed. For ships equipped with propellers permitting a level-flight propeller speed of 1,900, the ground speed of the propeller will be between 1,500 and 1,650 r.p.m., depending upon the type of the propeller used.

Do not operate the engine at full throttle on the ground for more than a moment or two. Continued running under these conditions is unnecessary and will result sometimes in damaging the engine. In some installations, the effective part of the propeller blades is so far removed from the crankshaft that insufficient cooling is provided for the engine while the plane is at rest, although the installation may be perfectly satisfactory while in the air.

Rough Running.—The usual cause for rough running, providing the ignition is functioning correctly and the carbureter is properly adjusted, is an unbalanced or fluttering propeller. The Wasp engine is carefully balanced at the factory and should run very smoothly. If it does not, the propeller should be inspected. First, if it is a metal propeller, the angle of the blades at the same station should be carefully checked on a surface plate with a protractor. Next, it should be balanced on a man-

drel and tracked. After this inspection, the blades should be observed for flutter while running at full speed on the ground. This condition may not exist at low engine speeds but becomes pronounced at full throttle. The substitution of a propeller from another ship which is known to run smoothly will sometimes be found a convenient check of this situation.

Oil Pressure.—Oil pressure should register immediately after starting. If there is no indication on the oil-pressure gage after 30 seconds, **stop** and check up the oil supply and especially the oil-suction pipe connections. A very small leak in the oil-suction line will prevent the oil pump from working properly. Do not continue running the engine unless oil pressure is obtained. The normal operating pressure is 75 to 90 pounds at 1,800 to 1,900 r.p.m. and 50 to 60 pounds idling. Average oil consumption is between 1 and 2 quarts per hour.

Low oil pressure is usually due to an air leak in the line from the oil tank to the pressure pump. For this reason, the connections should be carefully checked. Be sure that an adequate amount of hose, at least an inch, overlaps both the pipe and the connection on the engine, in order to have sufficient area for the hose clamp. No adjustment is provided for the oil pressure, as low pressure indicates trouble in the lubricating system which cannot be corrected by a new adjustment of the relief valve. If the connections are tight and the proper kind of oil used and still the pressure is low, it may be due to a loose cam bearing or a loose master-rod bearing. These two possibilities are very unlikely and should be investigated only after all other possible causes have been considered.

Excessive oil consumption and fouling of spark plugs may be due to an air leak in the pipe which takes oil from the sump to the suction pump on the engine. See if the flanged joints have good gaskets and are bolted up tight.

The oil outlet temperature should be 140° F. with a maximum of 170° F.

Oil Leaks.—Particular care has been taken in the design and manufacture of the Wasp engine to insure its being oil tight. Leakage is an indication of trouble and consequently should be investigated. For this reason, it is strongly recommended that the engine be kept clean, so that any oil leakage may be noticed and readily traced to its source.

The Wasp engine is designed to run on domestic aviation gasoline. Do not attempt to run at full throttle on ordinary automobile gasoline.

Only the best oil should be used. It should be free from acid. For air temperatures of 40 to 90° F. the open-cap flash point should be 465° F. as a minimum and a burning point of 520° F., and a specific gravity of 0.886 and a viscosity of 105–115 at 210° F. For weather below 40° F. use oil one grade lighter. All oil should be strained before pouring into the tank.

The mixture control should be kept at full rich for all flying below 5,000 feet, especially when landing. The mixture control should be used above 5,000 feet, being careful to adjust it so that the maximum r.p.m. is obtained. This can best be done by flying level with the throttle in the fixed position and observing the tachometer.

Treatment of New Engine.—Careful treatment of a new engine prolongs its life and is just as necessary as proper driving of a new automobile. Each engine is run approximately 15 hours at the factory before it is shipped, and it is thought that a total of at least 25 hours' careful running is desirable. During the first 10 or 15 hours of operation in the plane, it is well to warm up the engine gradually after each start and to stop gradually, also, rather than shut off suddenly from full speed. During this period, the engine should not be run wide open any more than absolutely necessary, and sudden acceleration should be avoided. The same precautions apply to some extent at any time during the life of the engine.

As a further aid in running a new engine, it is recommended that a pint of oil be added to each 10 gallons of gasoline for the first 10 hours of operation.

These measures, together with careful attention to maintaining the proper oil pressure and frequent change of oil, will result in polishing all moving parts so that long and trouble-free service will be rendered. *The first 10 hours in service are the most important in an engine's life.*

Caution.—The Wasp engine should render dependable service for long periods of time without disassembly, providing the engine is kept clean, properly adjusted, and operated as recommended. It is highly desirable not to disassemble the engine any more often than is absolutely necessary. Remember that most troubles can be overcome by external adjustment.

PERIODIC INSPECTION

After every 10 hours' flying, the engine should be given an external inspection for loose nuts and oil connections and oil leaks. The car-

bureter filter and engine oil filter should be cleaned. The spark-plug insulation should be wiped off, as dirt or soot on the outside of the plugs can cause short-circuiting.

After every 25 hours of flying, the valve-rocker axles should be lubricated with heavy cylinder oil (not grease) by means of a pressure gun. The felt plugs in the valve rockers require engine oil, which can be applied with an oil can after removing the valve covers. The only other parts of the engine not automatically lubricated are the two magnetos. These should be lubricated with a good grade of medium-bodied machine oil every 25 hours of flying. Put about 40 drops in the front oiler and 10 drops in the rear one.

The magneto-breaker points should be set with a maximum opening of 0.012 inch. The points must be kept clean and free from oil. Keep the breaker housing clean and free of excess oil. The felt wick should be kept saturated with oil at all times. Oil the carbureter throttle shaft bearings.

The proper valve clearance when cold is 0.010 inch for both the inlet and exhaust. This is measured between the valve stem and the valve adjusting screw ball which pushes the valve open. It is necessary to lift up the rocker arm against the pressure of a light spring before the clearance gage can be inserted. In checking valve clearances, the engine should be turned well past the point where the valve closes; otherwise, a false indication of clearance will be had. A box wrench for the valve-adjustment lock nut and a valve-clearance gage are found in the tool kit furnished with each engine. Some of the earlier engines have a cam giving the inlet valves a lift of $1\frac{1}{16}$ inch. Later engines, rated at 2,100 r.p.m. have a lift of $\frac{9}{16}$ inch for both valves. Do not try to check the valve timing with the running clearance of 0.010 inch. A special adjustment of the valve clearance of 0.060 inch on all valves for engines with the low lift cam and of 0.050 on the inlet and 0.060 inch on the exhaust valve with the high lift cam, must be made before the engine can be timed. While the covers are off for the purpose of checking clearance, it is well to look at the valve springs to make sure that none is broken. A valve spring can be replaced without removing its rocker arm. Depressing the valve with the tool provided allows one to take off the push-rod enclosure and push rod. The rocker arm can then be tipped up out of the way so that there is room to take out the valve spring.

Storage.—When the engine is to be taken out of service and put in storage, all dirty oil should be drained out. About 1 pint of clean engine oil should be put in each cylinder, and the crankshaft turned around several revolutions to make sure that the cylinder walls are well covered. Spark-plug holes should be closed either with plugs or corks, and the exterior of the engine cleaned. Oil the valve rockers, the carbureter throttle shaft, and the magnetos, and also oil all external bright metal parts.

TOP OVERHAUL

A top overhaul should not be necessary oftener than every 200 or 300 hours in normal service operation. Before commencing such work the engine should be checked to see that such an overhaul is really required.

Need for Top Overhaul.—The usual indication that an engine needs adjustment or possibly a top overhaul is the reduction in engine speed on the ground with full throttle. It should be borne in mind, in this connection, that extremes in temperature or barometer due either to atmospheric condition or altitude will affect the propeller speed sometimes as much as 50 to 100 r.p.m. and must be allowed for.

First check the mixture control to make sure that the lever on the carbureter is in the full-rich position when the control lever in the cockpit is in the corresponding location. Next, check the spark advance at the magnetos in the same manner. At the same time, check the magneto breakers with the feeler gage furnished for this purpose. The gap should be 0.012 inch. The points should be smooth and free from oil. Clean the strainers in the fuel-supply line, and be sure that fuel reaches the carbureter in adequate quantities. The best way to determine this is to disconnect the pipe at the carbureter and open the fuel valves, observing whether the pipe runs full of fuel or not. The valve and magneto timing should be checked. While this is being done, examine the valve springs for breakage.

After the above checking has been done, and adjustments made, if necessary, start the engine and warm it up at low speed (800 to 1,000 r.p.m.), until the temperature of the entering oil is at least 100° F. or 40° C. Next, try the engine at full throttle with the mixture control set full rich and the spark full advanced. Observe the r.p.m., oil pressure, which should be between 75 and 100, and fuel pressure, which should be between 3 and 4 pounds. Next, check the operation of the ignition by

running first on one magneto and then on the other. If the ignition is found satisfactory and fuel pressure is 3 or 4 pounds and the engine still does not turn up to the required ground speed, it is probable that a top overhaul is necessary. One other check, however, is suggested: After the engine has been stopped by running the fuel out and allowed to cool down for 5 minutes, the compression should be tried in the various cylinders. It will be necessary to turn the engine over two complete revolutions in order to test the compression in all nine cylinders. If this is found to be good, it is not likely that a top overhaul is needed, and there is probably some other reason for the loss in revolutions.

Disassembly.—Tools for making ordinary adjustments and minor repairs are found in the canvas tool roll furnished with each engine and includes the following special tools: valve-spring compressor, spanner for inlet-pipe nut, cylinder-nut wrench, box wrench for valve-adjustment locknut, valve-clearance gage. Ordinarily, a top overhaul can readily be accomplished while the engine is installed in the airplane.

First place the airplane in a clean, protected spot. Dust and dirt wear out more engines than anything else. Then remove the cowling surrounding the engine. Next, the engine should be thoroughly washed off with gasoline before attempting any disassembly work. With the engine thus prepared and some tins or boxes provided for the parts to be removed, the cylinder hats should be taken off. The push-rod enclosures are removed by telescoping the tubes and locking them by means of a slight twist, after which the valve springs should be compressed by means of the tool provided in the tool kit. This will permit the removal of the push rods and enclosures. In this operation, care should be taken that the valves are closed before trying to compress the springs. Although the push rods are marked at the tappet end to correspond with the cylinder numbers, it is best to lay them out in the order in which they are removed from the engine. It is highly desirable that they be replaced in the exact position from which they came, as the ball ends have been worn to a perfect seat.

With the push rods removed, the next operation is to take off the inlet pipes. In doing this, the spanner wrench provided should be used for loosening the packing at the bottom of each pipe before removing it. The packing nut should not be entirely unscrewed. Care should be taken in handling these intake pipes, as they are readily dented. Take off the oil sump, which is between the two bottom cylinders. There are

two oil pipes which connect to the top of this casting. The rear one stays in the engine, and the front one comes off with the sump. It is necessary carefully to pull the sump straight down in order to keep from bending these two pipes.

Cylinder 1 should be removed last and installed first. This cylinder positions the master rod. A special wrench will be found in the tool kit to remove the cylinder stud nuts, after which the cylinder can be readily removed. In doing this, however, care should be taken not to allow the piston to drop and thereby become nicked. Care should also be taken not to mar the bottoms of the cylinder barrels. These should be carefully set down on wood in order not to distort or burr the end of the barrel.

As soon as any one cylinder has been taken off, the piston should be removed by pushing out the wristpin. If this cannot be readily done, head or top of the piston should be slightly heated by means of a blow torch, and the pin tapped out by using a fiber drift shaped to fit the wristpin plug. Care must be taken not to drive these pins with any considerable force. The application of more heat will expand the piston sufficiently to enable the pins to be removed with ease.

Inspection of Connecting Rods.—With the cylinders removed, an inspection should be made of the master connecting rod and link rods. By moving each one, both up and down and sideways on the crankpin, a rough check can be made of the clearances. If these parts are in good condition, very little play will be found in the master rod, except sideways on the pin. The link rods (Fig. 6), however, will feel somewhat loose, as they have normally 0.002-inch clearance on the diameter of the pin and 0.006 to 0.008 inch sideways. It is advisable to try the wristpins in their respective rods. It should not be possible to insert more than a 0.002-inch feeler between the pin and the bushing. If more than 0.003-inch clearance is found, it is desirable to replace the bushing.

Unless the engine is particularly dirty, it is not advisable to wash the rods and shafts with gasoline, as it is rather difficult to re-oil them satisfactorily. Consequently, after the inspection, a large, clean piece of cloth or paper should be tied around the entire crankcase while the cylinders are being overhauled.

Removing Valves.—To facilitate the handling of the valves, a block of wood should be secured between 5 and 5½ inches in diameter and 11 inches long and rounded at the upper end to fit the cylinder dome.

Care should be taken that this wood is kept clean, as chips or dirt will readily mar the cylinder barrels. By placing the cylinder over this block, the valves will be held shut, and it will be easy to remove the valve springs by using the tool provided. It is not necessary or desirable to remove the rocker arms to take out the valve springs. As soon as the spring has been depressed, the split cone can be removed and the valve washer and valve springs taken out. After this is done, the locking wire should be removed; this will be found snapped into a groove near the outer end of the stem. Next, be sure that there is no burr on the valve stem, particularly at the edge of the lock-wire groove. In case there is, it should be removed with a fine file before attempting to remove the valves.

An examination should be made of the valve stems and their clearance in the valve guides before any regrinding is attempted. Care should be taken not to use emery cloth on the valve stems unless absolutely necessary, since it removes the glaze resulting from continued operation of the engine. The guide clearance can be checked by means of plug gages furnished in the station tool equipment. If the clearance is excessive, the valve guide should be replaced.

Valve Grinding.—Before attempting to regrind the valves, any excessive carbon should be removed from the cylinder heads, great care being taken not to mar the valve seats during the operation. The carbon should also be removed from the cylinder side of the valves. The valves should be carefully handled in order to avoid scratching or burring the seats.

Valve-grinding tools are provided for holding the inlet and exhaust valves while grinding. The grinding compound should be kept away from valve guides and cylinder bores, and all traces of it should be washed away after the grinding operation is finished.

As a rule, it should not be necessary to recut the valves or seats, lapping with grinding compound being sufficient to put both the valves and seats in good condition. After the valve grinding has been completed, the parts should be very thoroughly cleaned before reassembling, and the valve stems oiled, as well as the rocker balls, push-rod balls, and rocker-arm bearings. **Be sure to replace the safety snap rings on all valve stems as soon as the valves have been put into their guides.**

Inspection of the Pistons.—The piston rings should bear around their entire circumference and preferably have no more than 0.025-inch end

clearance when the ring is in the cylinder. Moreover, they should be entirely free in the ring grooves. If it is necessary to replace rings which do not meet these requirements, it is desirable to put the new rings in the lower grooves. In this way, the old rings which fit the cylinders will provide proper protection for the new rings until they are run in. New oil rings should be used if the scraping surface is more than half the width of the ring.



FIG. 6.—Rods assembled on crankshaft. This shows how the right small, or link rods, fit into main or mother rod.



FIG. 7.—The assembled cylinder. The aluminum head is shrunk on at 300° F. with both a plain and threaded fit.

The wristpin should be a push fit in the piston at room temperature, or 70° F. If it is too tight, the piston should be carefully reamed to provide the proper fit, using the reamer in the station tool equipment. It should be noted that, in cold weather, due to the contraction of the aluminum, the pin will be tighter than normally.

Before reassembling the cylinders on the crankcase, an examination should be made of the cylinder pads on the crankcase, and all burrs, etc., should be removed; these might cause oil leaks. A cylinder is shown in Fig. 7, mounted on a convenient base for assembling the valves. (The rods are shown assembled on the crank shaft in Fig. 6.)

Assembling.—To reassemble the engine, replace piston 1 on the master rod with the piston number facing the propeller. Carefully space the piston rings so that the slots on the compression rings are 120 degrees apart; in other words, so that they are spaced equally around the piston. *See that the oil-scraper ring is in place, with the scraping edge toward the bottom.* Next, carefully oil the piston with clean engine oil, and wipe out the cylinder barrel and oil it. After this is done, compress the piston rings by means of the ring clamp provided in the

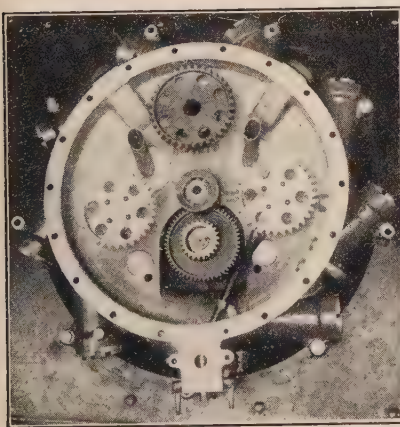


FIG. 8.—Blower section of the supercharger, showing the gears in the front chamber for driving auxiliary machinery.



FIG. 9.—The impeller of the supercharger which is driven at five times the crankshaft speed by step-up gears.

station kit, and put on cylinder 1, which should be carefully and completely fastened down before attempting to install the next cylinder. The hold-down nuts should be tightened down evenly all around with the wrench provided and safety wired. Repeat the above process for the installation of the other eight cylinders, and then replace the push rods in their enclosing tubes, being careful to put them back in the same position as they formerly had. Be sure, moreover, that the gaskets at both ends of the enclosure tubes are in good shape and in proper position. Next, attach the intake pipes, being careful that the packing end of the pipe is round and smooth. The three-cornered intake gasket

on the cylinder should be in good condition. If not, replace it. Do not tighten down on the packing nuts with anything but the spanner wrench provided in the tool kit, and note that these nuts should not be tightened up too tight, or damage will be done to the intake pipes.

With the cylinders, push rods, and intake pipes in place, set the valve clearance to 0.010 inch, using the box wrench provided. It is essential to turn the engine half a revolution from the intake closing before attempting to set the tappet clearance for any particular cylinder. This will insure the valves' being on their seats. As there is a spring in each tappet which keeps the push rod engaged with the rocker arm, it is necessary to lift the rocker arm in order to insert the clearance gage. It is not necessary to retime the engine after a top overhaul, as the cam mechanism is not disturbed.

Figure 8 shows the blower section of the supercharger which consists of two chambers. It shows the gears in the front chamber for driving the auxiliary mechanisms in the rear section. Figure 9 shows the impeller of the supercharger.

Before replacing the oil sump, remove the screen and clean it. Be careful that the front pipe is in place in the sump and the rear pipe in the blower section, and that both are round and smooth. *Do not force the sump up into place.* The suction pipe which takes oil from the bottom of the sump must have a good gasket and must be bolted up tight.

Before attempting to start the engine, the routine inspection referred to in the paragraphs on Periodic Inspection should be conducted.

Running In.—It is desirable to operate an engine which has been given a top overhaul for 2 to 3 hours with gradually increasing speed before attempting to run the engine at full throttle or fly the plane. This running should be done before replacing the engine cowling. Afterward, a check should be made for oil leaks and the tightness of all connections, etc. If a whole new set of rings has been used on any one piston, or other new parts installed, it is desirable to run the engine at least 2 hours more, and it is preferable to operate it with the least possible amount of full throttle running for 5 or 10 hours thereafter, in order that the new parts may be properly run in and seasoned. If the engine turns up to its customary ground speed, and the oil pressure is between 75 and 100 pounds at full throttle, the engine can be considered in good shape and ready for further service. After running in, the valve clearance should be rechecked, as the valves may have bedded in somewhat.

The engine must be cold when the clearance is checked, or a false indication will be given.

TABLE OF FITS—WASP ENGINE

(When three figures are given, the second figure indicates the *desired* fit. The other two give the tightest and loosest fits permissible. Dimensions given in inches T means tight and L loose.)

Thrust bearing and case—end clearance	0.0036 T	0.0025 T	0.0074 L
Thrust bearing cover ring and case— diameter.....	0.0315 L	0.037 L	0.0425 L
Thrust bearing cover and case—diam- eter.....	0.0035 L	0.005 L	0.0065 L
Thrust bearing and case—diameter....	0.0003 T	0.001 L	0.0015 L
Thrust bearing and spacer—diameter..	.....	0.0002 T	0.0014 T
Thrust bearing spacer and crankshaft— diameter.....	0.0005 L	0.001 L	0.0025 L
Crankshaft and plug.....	0.0005 T	0.002 T	0.0035 T
Thrust-bearing spacer and key—side clearance.....	0.0005 T	0.001 L	0.0025 L
Crankshaft and key.....	0.0005 L	0.000	0.0015 T
Thrust bearing spacer and key—top clearance.....	0.007 L	0.016 L	0.025 L
Cam drum and bushing.....	0.0065 L	0.008 L	0.0095 L
Cam drum—end clearance—fit to.....	.....	0.008 L	
Cam-drive gear and ring.....	0.001 L	0.001 T	0.003 T
Cam-bearing spacer and gear—lug side clearance.....	0.000	0.004 L	0.008 L
Cam-drive gear and crankshaft—also cam-bearing spacer and crankshaft...	0.0005 L	0.001 L	0.0025 L
Front main bearing and crankshaft....	0.0003 L	0.000	0.0013 T
Front main bearing and liner.....	0.001 L	0.0008 L	0.0028 L
Front main bearing liner and case....	0.008 T	0.010 T	0.012 T
Front main bearing liner and case (large diameter).....	0.002 L	0.005 L	0.008 L
Crankshaft and pin.....	0.000	0.0025 T	0.005 T
Cam drum and cam.....	0.0025 T	0.001 T	0.0005 T
Crankcase main and front.....	0.000	0.001 L	0.004 L
Crankcase main and blower.....	0.000	0.001 L	0.004 L
Blower and rear case.....	0.000	0.001 L	0.004 L
Main crankcase and bolt.....	0.0005 T	0.0015 L	0.0015 L

TABLE OF FITS—WASP ENGINE.—(Continued)

Cam reduction gear and bushing—end clearance.....	0.004 L	0.008 L	0.012 L
Main crankcase and cam-reduction gear nut—end clearance.....	0.006 L	0.011 L	0.016 L
Cam-reduction gear and bushing—diameter.....	0.001 L	0.002 L	0.003 L
Main crankcase and cam-reduction gear bushing.....	0.001 T	0.002 T	0.003 T
Cam-reduction and cam-countershaft gear.....	0.002 L	0.000	0.002 T
Valve tappet and pin.....	0.000	0.001 L	0.002 L
Valve-tappet roller and pin.....	0.000	0.001 L	0.002 L
Valve tappet and valve-tappet roller—side clearance.....	0.008 L	0.014 L	0.020 L
Valve-tappet guide and roller—side clearance.....	0.000	0.003 L	0.006 L
Tappet guide and pin.....	0.002 L	0.005 L	0.009 L
Tappet guide and roller pin—end clearance.....	0.021 L	0.031 L	0.041 L
Valve guide and valve.....	0.003 L	0.007 L	0.010 L
Front crankcase and valve guide.....	0.0005 L	0.000	0.001 T
Valve tappet and valve guide.....	0.000	0.0005 L	0.001 L
Valve tappet and push-rod socket.....	0.0005 T	0.0015 T	0.0025 T
Push-rod ball end and push rod.....	0.0005 T	0.0015 T	0.0025 T
Push-rod ball end and pin.....	0.009 T	0.000	0.014 L
Push-rod tube, inner and outer.....	0.002 L	0.004 L	0.006 L
Cylinder head and valve seat.....	0.0065 T	0.008 T	0.0095 T
Exhaust valve and valve guide.....	0.005 L	0.006 L	0.007 L
Cylinder head and valve guide—inlet and exhaust.....	0.0005 T	0.002 T	0.0025 T
Cylinder head and push-rod tube.....	0.020 L	0.010 L	0.005 T
Inlet valve and valve guide.....	0.0015 L	0.002 L	0.0035 L
Piston and cylinder sleeve (upper).....	0.036 L	0.038 L	0.040 L
Piston and cylinder sleeve (lower).....	0.028 L	0.030 L	0.032 L
Piston pin and plug.....	0.0015 T	0.0025 T	0.0035 T
Master rod and bushing.....	0.0015 T	0.002 T	0.0045 T
Piston pin and bushing.....	0.00175 L	0.0025 L	0.00325 L

TABLE OF FITS—WASP ENGINE.—(Continued)

Piston and piston pin.....	0.00015 L	0.0008 L	0.00125 L
Cylinder sleeve and piston-pin plug— end clearance.....	0.036 L	0.052 L	0.068 L
Main crankcase and cylinder sleeve....	0.002 L	0.007 L	0.012 L
Crankshaft front and crankshaft rear— large diameter.....	0.000	0.0005 T	0.001 T
Master rod and bearing.....	0.000	0.001 T	0.002 T
Crankshaft front and bearing.....	0.002 L	0.0025 L	0.003 L
Crankshaft and bearing—end clearance		0.012 L	0.0195 L
Crankshaft rear and bolt.....	0.001 L	0.003 L	0.005 L
Articulated rod pin and master rod....		0.000	0.001 T
Articulated rod pin and plug.....	0.000	0.0015 T	0.003 T
Master rod and bushing—end clearance	Fit to 0.006 inches L to 0.008 inches L at assembly		
Articulated rod and master rod—end clearance.....	0.011 L	0.015 L	0.019 L
Master rod and articulated rod pin....	0.0005 L	0.000	0.001 T
Articulated rod pin and bushing.....	0.001 L	0.0015 L	0.0025 L
Articulated rod and bushing.....	0.0015 T	0.002 T	0.0045 T
Rear main bearing and liner.....	0.0003 T	0.0008 L	0.0015 L
Crankshaft and main bearing—rear....	0.0001 L	0.000	0.0015 T
Main bearing liner rear and crankcase..	0.008 T	0.010 T	0.012 T
Blower-shaft bearing cage and case....	0.000	0.001 T	0.002 T
Blower-shaft bearing cage and ball bearing.....	0.0003 T	0.0006 L	0.0015 L
Blower shaft and impeller spline fit— outside diameter.....	0.000	0.001 L	0.002 L
Blower shaft and impeller spline fit— inside diameter.....	0.000	0.001 L	0.004 L
Blower shaft and impeller-spline fit— width.....	0.0005 T	0.0002 L	0.0015 L
Blower shaft and ball bearing.....	0.000	0.0005 T	0.001 T
Blower case and ball bearing.....	0.0004 L	0.001 L	0.0014 L
Cylinder head and rocker shaft—ball bearing.....	0.0003 T	0.0008 L	0.0013 L
Rocker shaft and ball bearing.....	0.0001 L	0.000	0.0007 T
Valve rocker and shaft (diameter)....		0.000	0.0004 T

TABLE OF FITS—WASP ENGINE.—(Continued)

Valve rocker and shaft—end clearance.	0.0004 T	0.006 L	0.0156 L
Cylinder head and rocker bearing cover	0.000	0.004 L	0.008 L
Rocker bearing cover and bolt.....	0.000	0.004 L	0.009 L
Magneto advance—yoke and pin.....	0.0005 T	0.001 L	0.0025 L
Oil pump end plate and body.....	0.000	0.001 L	0.004 L
Oil pump body and rear case.....	0.000	0.002 L	0.002 L
Oil-pump drive gear and key.....	0.001 T	0.0005 T	0.001 L
Oil-pressure gear and key.....	0.001 T	0.0005 L	0.003 L
Oil-suction idler gear and body—end clearance.....	0.001 L	0.003 L	0.005 L
Oil-pump drive gear and oil-pump idler shaft in oil-pump end plate.....	0.001 L	0.002 L	0.003 L
Oil-pressure idler gear and oil-idler suction gear in oil-pump body and oil-pump pressure body.....	0.005 L	0.007 L	0.009 L
Magneto drive shaft and bushings.....	0.001 L	0.002 L	0.003 L
Magneto drive shaft and key.....	0.001 T	0.000	0.002 L
Steel propeller hub snap ring and propeller hub—side clearance.....	0.001 L	0.004 L	0.007 L
Crankshaft and propeller hub—side clearance.....	0.0005 L	0.001 L	0.0035 L
Crankshaft and propeller hub—outside diameter.....	0.005 L	0.010 L	0.014 L
Crankshaft and propeller hub—inside diameter.....	0.001 L	0.010 L	0.015 L
Propeller hub clamp, female and head pin.....	0.000	0.001 L	0.003 L
Crankshaft rear and crankshaft front—small diameter.....	0.0005 T	0.001 T	0.0015 T
Blower-shaft ball-bearing closure and blower-shaft bearing cage.....	0.0005 T	0.0005 L	0.0015 L
Blower impeller and case (fit to 0.015 to 0.020 inches).....			
Generator drive gear and ball bearing I.D.....	0.0001 L	0.0005 T	0.0009 T
Generator support and ball bearing O.D.....	0.0005 T	0.0005 L	0.0013 L

TABLE OF FITS—WASP ENGINE.—(Continued)

Generator support and ball bearing— end clearance.....	0.0013 L	0.003 T	0.0077 T
Valve rocker bearing bushing and cylin- der head.....	0.0015 T	0.002 T	0.005 T
Valve rocker and cup.....	0.000	0.001 T	0.0025 T

THE HORNET ENGINE

The Pratt and Whitney Hornet engine is of the same general design as the Wasp but is larger. The Hornet has nine radial cylinders of $6\frac{1}{8}$ inch bore and $6\frac{3}{8}$ inch stroke. The outstanding features of the Wasp are also embodied in the Hornet and include a one-piece master connecting rod, two-piece crankshaft, forged duralumin crankcase, enclosed valve gear, built in supercharger, and the grouping of all accessories at the rear.

The design of the Hornet engine is such that 87 per cent of the parts used in its construction are interchangeable with the similar parts of the Wasp engine. The rear half of the engine and all accessories but the starter are identically the same as those used on the Wasp. In addition to these, the sump and many of the small engine parts are interchangeable. This system of construction has the highly desirable result of reducing the quantity of parts that must be carried in reserve where both the Wasp and Hornet engines are used.

The main crankcase, nose section, crankshaft, cam, pistons, and cylinders are larger than the corresponding Wasp parts. Tappets, breathers, and some of the push rod and push-rod cover parts are the same pieces used on the Wasp but the tappet guides, valves, and valve springs are different. A larger size of starter is used and the carbureter is equipped with larger chokes.

The same considerations apply to the mounting of the Hornet engine as to the Wasp. On account of the large size of the Hornet cylinder, free circulation of cooling air is essential and the cowling must be so constructed as to expose all of the cylinder-head casting and at least a part of the cylinder barrel. There should be no large diameter cowling or exhaust manifold immediately back of the engine to obstruct the flow of air away from the engine. It is also desirable to have a

good circulation of air all around the crankcase of the engine and around the oil tank to assist in keeping the oil cool. *A three-bladed propeller should be used.*

The suggestions on the operation of the Wasp apply equally to the Hornet. An additional precaution is necessary, however, in the case of the latter, owing to the larger size of propeller used. *Do not operate the engine at full throttle on the ground longer than necessary to check the maximum speed.* The effective part of the propeller blade is so far removed from the crankshaft that insufficient cooling is provided for the engine while the plane is at rest, although the installation may be perfectly satisfactory while in the air.

INSPECTION AND OVERHAUL

The same rules apply for the Hornet as for the Wasp. The valve clearance when cold is 0.010 inch for both inlet and exhaust. The instructions for overhaul are written to specifically cover the Wasp, and the following points of difference should be noted when working on the Hornet engine:

The wood block which is placed inside the cylinder to facilitate handling the valves will be 12 inches long.

When timing the Hornet engine, set the valves of cylinder 1 with 0.062 inch clearance (on both inlet and exhaust), being sure that the cam is at the lowest point when this is done. After completing the timing operation, set the clearance of all valves to 0.010 inch.

CHAPTER 4

WRIGHT WHIRLWIND ENGINE J-6

The Whirlwind engine (manufactured by the Wright Aeronautical Corporation, Paterson, N. J.) has undergone several changes; the J-5 having given way to the J-6 which is built in three sizes, developing 150, 225, and 300 horsepower respectively. The cylinders are all of the same size, 5-inch bore by 5½-inch stroke, the power being secured by using five, seven, and nine cylinders. As 94 per cent of the parts are alike on three engines, the data applies to all three sizes in nearly all cases. The cylinders are numbered clockwise as viewed from the rear of the

engine, No. 1 being at the top. Two views of the new engine are seen in Figs. 1 and 2. They are all fixed, radial and air-cooled.

The main specifications are:

	Nine	Seven	Five
Model.....	R-975A	r-760A	R-540A
Number of cylinders.....	9	7	5
Bore, inches.....	5	5	5
Stroke, inches.....	5.5	5.5	5.5
Piston displacement, in cubic inches....	972	756	540
Compression ratio.....	5.1:1	5.1:1	5.1:1
Normal speed, in r.p.m.....	2,900	2,000	2,000
Normal brake horsepower, at sea level and at normal r.p.m. with aviation gasoline.....	320	235	170
Guaranteed brake horsepower, at sea level and at normal r.p.m. with aviation gasoline.....	300	225	165
Direction of rotation of crankshaft, looking at rear end of engine.....	Clockwise	Clockwise	Clockwise
Average weight of engine, pounds.....	530	455	380
Position of center of gravity: Distance forward of rear face of mounting bosses, inches.....	7.0	7.0	6.5
Distance above center line of crank- shaft, inches.....	0.2	0.3	0.3
Diameter of mounting bolt circle, inches	19 $\frac{1}{4}$	19 $\frac{1}{4}$	19 $\frac{1}{4}$
Number of mounting bolts.....	8	8	8
Size of mounting bolts, inches.....	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{3}{8}$
Overall diameter of engine, inches.....	45	45	45

Ignition

	V-AG9-DF	MN7-D-F	MN5-D-F
Magneto type (Scintilla).....	Counter- clockwise	Counter- clockwise	Counter- clockwise
Direction of rotation of magneto drive, looking at drive end.			
Magneto speed, in multiples of crank- shaft speed.....	$\frac{9}{8}$	$\frac{7}{8}$	$\frac{5}{4}$
Magneto breaker point gap, inches.....	0.012	0.012	0.012

	Nine	Seven	Five
Ignition (Cont.)			
Spark plug gap:			
A. C. plugs, inches.....	0.025	0.025	0.025
B. G. plugs, inches.....	0.015	0.015	0.015
Spark occurs, in degrees before top center:			
Right magneto.....	25	25	25
Left magneto.....	25	25	25

Valves and timing

Intake opens, in degrees before top center.....	10	10	10
Intake closes, in degrees after bottom center.....	60	60	60
Exhaust opens, in degrees before bottom center.....	75	75	75
Exhaust closes, in degrees after top center.....	30	30	30
Intake remains open, in crankshaft degrees.....	250	250	250
Exhaust remains open, in crankshaft degrees.....	285	285	285
Valve lift, inches.....	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{9}{16}$
Valve rocker clearance, both valves, cold:			
Timing, inches.....	0.070	0.070	0.070
Running, inches.....	0.010	0.010	0.010

Fuel system

Carbureter type (Stromberg).....	NA-R9	NA-R7	NA-R7
Guaranteed fuel consumption at guaranteed power and normal r.p.m., in pounds per brake horsepower-hour...	0.55	0.55	0.55
Fuel pressure, in pounds per square inch	2 to 4	2 to 4	2 to 4

Lubrication system

	Nine	Seven	Five
Guaranteed oil consumption at guaranteed power and normal r.p.m., in pounds per brake horsepower-hour	0.035	0.035	0.035
Oil pressure, in pounds per square inch:			
Minimum idling.....	15	15	15
At normal r.p.m. and normal oil temperature.....	40-60	40-60	40-60
Minimum safe quantity of oil in whole system, gallons.....	4	4	4
Desired oil outlet temperature in normal operation, degrees Fahrenheit.....	140	140	140
Maximum permissible oil outlet temperature under worst conditions, degrees Fahrenheit.....	190	190	190
Speed of oil pump, in multiples of crankshaft speed.....	1	1	1
Hose connection nipples, outside diameter, inches.....	1	1	1

Accessory drives and instrument connections

Oil temperature (USN-USAC Standard).....	5/8 inch-18 P
Oil pressure.....	1/8 inch pipe tap
Oil-tank vent.....	3/8 inch pipe tap
Fuel-pump flange and drive.....	US Air Corps. Type C-5
Fuel-pump speed.....	Crankshaft
Fuel pump, direction of rotation (Observer facing rear of engine).....	Counter-clockwise
Starter flange and drive.....	US Air Corps
Starter rotation (Observer facing rear of engine)....	Counter-clockwise
Starter shaft speed.....	1/2 c.s. 1/8 c.s. 1/8 c.s.
Generator flange and drive.....	USAC E-3 or E-4
Generator speed.....	1.43 times crankshaft
Generator direction of rotation (Observer facing rear of engine).....	Counter-clockwise
Tachometer drive shaft.....	US Air Corps
Tachometer drive speed.....	1/2 crankshaft
Tachometer drive direction of rotation.....	one clockwise, one counter-clockwise
Propeller hub spline.....	S. A. E. No. 30

Weights of accessories

	Nine	Seven	Five
Fuel pump, pounds.....	2.5	2.5	2.5
Hand starter (Eclipse Series 6).....	20.0	20.0	20.0
Hand-starter crank and extension shaft	5.0	5.0	5.0
Propeller hub, for two-bladed metal propeller.....	23.0	23.0	23.0
Exhaust manifold.....	27.0	24.0	20.0
Nose cowling.....	6.0	6.0	6.0
Air cleaner and adapter.....	5.75	5.75	5.75
Air heater and cleaner.....	8.75	8.75	8.75
Generator (Eclipse Model G-1).....	16.0	16.0	16.0

The engine-mounting ring for the J-6 must be of larger diameter than the engine-bolt circle and must have lugs that project inwardly so as to provide clearance over the magnetos and give greater accessibility to fuel, oil, and tachometer connections.

In laying out the engine mount, space should be allowed for the airmaze and heater as shown on Wright Aeronautical Corporation installation drawings, these parts being furnished in place of the "hot spot" after approximately the one hundredth engine.

Cowling.—Attention is called to the fact that, due to the increased power developed per cubic inch of displacement, these engines require more cooling than the J-5. The standard nose cowl furnished with the engine is designed so that part of the air is admitted through holes in the central portion. It is absolutely essential that ample provision be made for the flow of this air around the crankcase and lower portions of the cylinder barrels. This is accomplished by providing a large number of louvers in the cowl in rear of the engine and eliminating as far as possible the restriction of the air flow in the rear of the engine section.

Flight tests indicate that, except in very cold weather, *i.e.*, below zero Fahrenheit, it is not necessary to close the shutters in the nose cowl. In warming up on the ground, moreover, practically no air is forced through the holes in the nose cowl so that the engine can be warmed up as quickly with the shutters open as with them closed. For this reason,

although provision has been made for attaching a control lead to the shutter, it is not necessary to arrange for cockpit control.

In order to avoid interference with the nose cowl it is necessary that the clamp rings on the metal propeller hubs be turned so that the bolts and hinges are on the sides instead of front and rear. Propeller manufacturers will balance propellers with the rings in this position.

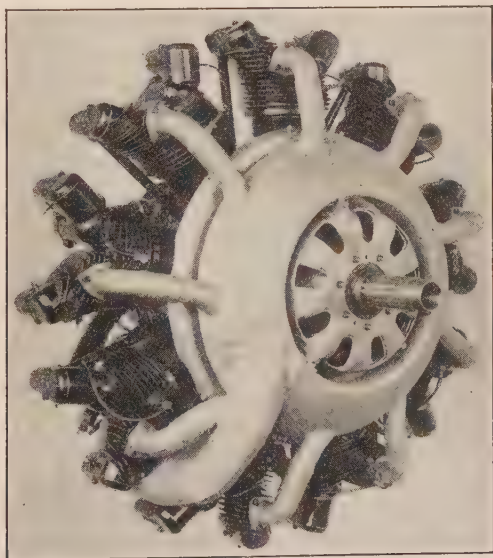


FIG. 1.—Front end of J-6, R-975-300 horsepower.

From results obtained to date it is apparent that it is not practicable to use the N. A. C. A. type of outer cowling over the nose cowl and exhaust manifold furnished with the engine. The Wright Corporation is making up a special combination of exhaust manifold and cowling of the N. A. C. A. type.

Exhaust System.—An exhaust manifold is furnished with the engine. There are two elliptical tail-pipe outlets on the Nine and a single circular outlet on the Seven and the Five. These manifolds are made of black iron and, while this material resists corrosion, it is recommended

that some protective coating be used. Before shipment the manifolds are coated with a heat-resistant graphite paint. While this material has been found quite satisfactory, and is recommended for use, it will be necessary to renew it occasionally, particularly if the plane is flown through rain. If it is at any time impossible to obtain this type of paint, ordinary stove polish may be used.



FIG. 2.—Back of J-6-300 horsepower Whirlwind.

The first one hundred Whirlwind Nine engines have an elbow on the exhaust manifold for the attachment of the pipe to the mixture heater or hot spot which is furnished with these engines. In order that this extension may be properly located, it is necessary that the two-tail pipe elbows be placed between cylinders 4 and 5 and cylinders 6 and 7.

After the one hundredth Nine engine and on all Whirlwind Seven and Whirlwind Five engines, the hot spot was replaced with the air heater mentioned above. The hot-spot elbow was then eliminated and the exhaust manifold turned so that one of the tail pipes passes directly beneath the carbureter.

Fuel and Oil Lines.—All fuel and oil lines should be as short and as straight as possible in order to avoid "air locks." Brace all lines well to guard against vibration and chafing.

Locate the oil strainer furnished with the engine in the "oil out" line and at a point where it is easily accessible.

Lubrication System.—The oil tank should be located so that it is exposed to an air flow on all sides and at such a height that the level of the oil in the tank is above the engine oil pump, thus eliminating priming difficulties.

The vent from the tank may be piped into the engine crankcase, using $\frac{1}{2}$ -inch piping and entering the crankcase through a $\frac{3}{8}$ -inch pipe tap hole in the rear section of the case. With the vent installed in this fashion, oil will not be spilled from the tank during stunt maneuvers of the plane.

The oil-pressure line should be to $\frac{3}{8}$ -inch in diameter with ordinary length of line, connecting the pressure gage on the instrument board with the pressure outlet on the left side of the oil pump.

The oil-temperature thermometer should be located in the $\frac{5}{8}$ -inch 18P hole provided in the oil strainer cover.

An additional thermometer connection, to be used for test purposes, is provided on the lower left side of the rear section of the crankcase. A thermometer installed in this connection measures the temperature of the oil coming from piston and cylinder walls which is considerably higher than that of the outlet oil. This temperature also fluctuates rapidly with changes in throttle openings. If this connection is used, there should be no cause for alarm if this temperature runs in excess of 200° F., provided the temperature of the oil at the strainer does not exceed 190° F.

Flight tests indicate the absolute necessity for cooling the oil. As this may be done in a number of ways and each plane presents its own problem, no specific recommendations can be made. As suggestions, however, the use of finned tubing in the oil-return line, scoops, forcing cold air through tubes through the oil tank, or a separate oil radiator are worthy of mention.

Fuel System.—The standard Army-Navy fuel-pump mount and drive are provided, permitting the installation of any one of several types of fuel pumps without alteration. The pump discharge should be connected to the carbureter and the pressure relief line should be

pipled back to the fuel tank. If a pressure-relief valve is not supplied with the type of pump employed and the pump feeds directly to the carbureter, one must be provided as a separate unit, situated in the fuel line between the carbureter and the pump.

If no pump is used, the carbureter should be connected to a gravity-feed tank through $\frac{3}{8}$ inch piping. This tank should have at least a 20-inch head when the plane is inclined at its steepest angle of climb. This will insure a steady flow of gasoline to the carbureter.

The priming pump is furnished with a "shut-off" valve located near the primer plunger and provided with a right-angled handle which will extend across the plunger handle when in the "Off" position, indicating in a clear and forceful manner whether or not the line is closed. This is a matter of utmost importance, as leakage through the priming line is liable to flood the lower cylinders with raw gasoline and cause considerable damage.

The primer-fuel supply is drawn from the main fuel line through the reducing tee furnished with the engine and the primer discharge is connected to the diffuser chamber at the base of cylinder 1 intake pipe.

Magneto Wiring.—Connect the top connections "P" of the magnetos to the points marked "R Mag" and "L Mag" on the ignition switch. Connect the point marked "Grd" on the ignition switch to the engine crankcase. Protect these lines carefully against chafing and wear.

If a booster magneto is installed in the plane, connect the high-tension lead of the booster to the point marked "H" on either magneto. The booster magneto frame must be grounded to the engine crankcase.

Tachometer Drive Connections.—A dual tachometer drive is located on the right of the rear section just above the fuel pump. The connections are U. S. Air Corps standard with a $\frac{7}{8}$ inch-18 thread. The drives rotate at one-half crankshaft speed.

Starter.—Any one of several types of starters can be used. A rigid, outside bearing in line with the starter shaft will be necessary. This bearing should have sufficient clearance to allow for slight misalignment of the hand crank and starter shaft. A push-pull control is needed for operating the engine dog.

Propeller and Hub.—The propeller blade angles should be set to allow the engine to turn at approximately rated speed at full throttle with the plane in level flight.

OPERATION

Starting Preparations.—After the installation of the engine in the plane, fill the gasoline tank with a good grade of domestic aviation gasoline, see that there is at least 5 gallons of good quality aviation engine oil in the oil tank, make sure that the priming pump and hand-fuel pump (if installed) are in proper working order, operate all controls to see that they are unrestricted throughout their ranges, and turn the engine through at least four revolutions by hand to ascertain that everything is clear.

Starting.—Prime the engine, ordinarily with seven or eight strokes, more if the engine is cold. With throttle control "Closed," mixture control "Full rich" and spark control "Full advance," operate the starter. The carbureters on these engines are equipped with a pump for supplying the accelerating charge of fuel. This may be used as an aid to starting, by moving the throttle back and forth from closed to about three-fourths open. If the engine shows a tendency to kick back, retard the spark about halfway.

As soon as the engine fires, advance the throttle until the tachometer registers a speed of 600 r.p.m. and adjust the spark control to the Full advance position. Should the engine fail to start after several attempts, reprime it and try again. If the engine appears to be over-primed, it should be turned backwards a revolution or two with the ignition switch Off and the throttle Open.

In extremely cold weather, it will be necessary to heat the oil before attempting to start the engine.

Ground Test.—As soon as the engine starts, watch the oil gage for pressure. If this does not rise to 15 pounds within 1 minute, stop the engine and investigate the trouble.

After the oil gage indicates pressure, run the engine at 600 to 800 r.p.m., holding that speed until the temperature of the oil reaches 85° F. Slowly increase the speed to full throttle. Observe the tachometer and oil-gage readings to see that they are normal. Check the functioning of the engine when operating on one magneto at a time. The r.p.m. on one magneto should not drop more than 75 below the reading when operating on both magnetos.

Do not prolong full throttle running on the ground as the engine receives very poor cooling when not in flight.

Daily inspection is practically the same as for the J-5. Some of the suggestions for the 20-hour inspection are however slightly different and are given below:

See that the propeller hub nut is tight.

Check the spark plugs for cleanness and proper gap (A.C. 0.025 inch, B.G. 0.015 inch).

Examine the cylinder hold-down nuts for tightness and see that each is properly locked in place.

See that the capscrews on the intake pipe flanges are tight.

Check the mounting bolts for tightness.

Remove the rocker-box covers and check the valve-operating parts for wear. The engine should always be cold when checking the valve-tappet clearance.

See that the fuel and oil strainers are clean.

Drain the oil and replace with a fresh supply.

Examine the carburetor and hot spot (or air heater) flanges for tightness.

Grease the upper push-rod ball ends with a graphite grease. *Under no circumstances should this grease be used on the rocker-arm ball bearings.*

See that each magneto gets full advance when operated from the cockpit.

Check the magneto-breaker points for cleanness and proper gap (0.012 inch).

Put four drops of medium machine oil in the magneto rear holes. Fill the magneto front holes. Do not overoil the magnetos as trouble is sure to result.

Remove the air maze, clean it by rinsing in a pail of gasoline, and dip it in fresh oil before replacing it on the engine.

Lubricate those parts of the control mechanism where friction is present.

General.—If the plane is out of service for an extended period of time, the engine should be run at part throttle at least $\frac{1}{4}$ or $\frac{1}{2}$ hour twice a week in order to keep the interior parts flushed with oil. This will prevent rusting of steel parts from vapor formed by condensation within the crankcase.

Experience to date indicates that the rocker arms should be lightly greased about every 50 hours, using a grease free from graphite or soap.

The length of time between overhauls depends entirely upon the severity of the service to which the engine is subjected. Under normal conditions of operation and service the engine will operate satisfactorily for 200 to 300 hours before a complete dismantling and overhauling is

required. Where the service is severe and the conditions abnormal, the overhauls may be more frequent.

WHIRLWIND J-5 ENGINES

The thousands of J-5 engines in service make it necessary to repeat the information in the last edition, together with some new suggestions regarding the proper servicing of these engines. Front and back views

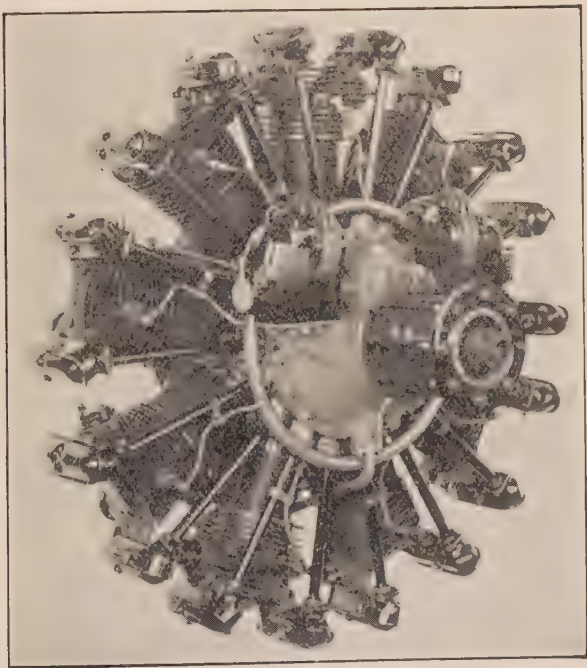


FIG. 3.—Front side of Wright Whirlwind J-5 engine.

are shown in Figs. 3 and 4. This information was prepared in cooperation with the builders. It is intended, primarily, for the use of those in charge of a number of engines, but it covers the whole field. The airplane designer will find information that is helpful in providing the best installation, the pilot for handling the engine, and the hangar man will find hints on its daily care. Perhaps the greatest attention has been

given to the notes on disassembly and inspection. The methods followed were decided after careful consideration of factory procedure and conditions in the field. Particular emphasis is given to instructions on some points which may appear to the reader to be of small importance. Great care has been taken, however, not to stress anything unduly.

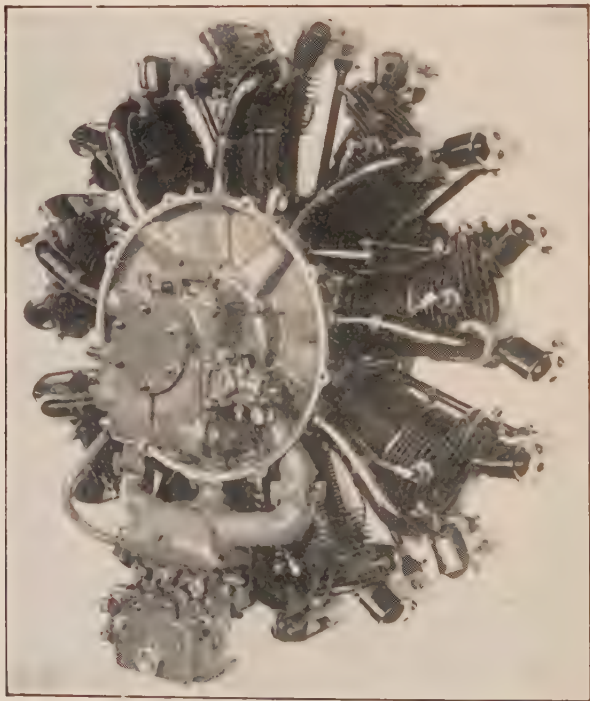


FIG. 4.—Rear of Wright Whirlwind J-5 engine.

When small matters have been made very prominent, it is because experience has dictated that these points must be given especial care. It has been assumed that the mechanic who does the work will be fully acquainted with the grade of workmanship necessary for aviation-engine repair; hence, there is no reference to elementary points of craftsmanship.

GENERAL SPECIFICATIONS FOR J-4A, J-4B, AND J-5 ENGINES

	J-4A and J-4B	J-5
Average horsepower at normal r.p.m.	{ 212 J-4A } { 220 J-4B }	220
Type	Air cooled	Air cooled
1. Number of cylinders	9	9
2. Bore, inches	4.5	4.5
3. Stroke, inches	5.5	5.5
4. Piston displacement, cubic inches.	788	788
5. Compression ratio	5.3	5.4
6. Normal speed in r.p.m.	1,800	1,800
7. Guaranteed brake horsepower, sea level at normal r.p.m. with aviation gasoline	200	200
8. Direction of rotation of crankshaft (looking at propeller end of engine)	Counter-clockwise	Counter-clockwise
9. Direction of rotation of cam (looking at propeller end of engine)	Clockwise	Clockwise
10. Tachometer shaft speed	Half crankshaft	Half crankshaft
11. Direction of rotation tachometer shaft (looking into open end of tachometer drive)	Counter-clockwise	Counter-clockwise
12. Average weight of engine complete with propeller hub, flange, and bolts, carbureter, and two magnetos, without oil radiators, tanks, starting device, gasoline system, propeller, fuel pump, or generator, pounds	478	
13. Average weight of engine complete with carbureter, two running magnetos, spark plugs, high-tension wiring, and synchronizer drives, without oil, exhaust pipes, exhaust flanges, starting device, fuel pump, propeller hub, flange, and bolts (propeller-hub assembly 13 pounds additional weight), pounds		500
14. Diameter mounting-bolt circle, inches	19 $\frac{1}{4}$	19 $\frac{1}{4}$
15. Number of mounting bolts	8 total	8 total

GENERAL SPECIFICATIONS FOR J-4A, J-4B, AND J-5 ENGINES.—(Continued)

	J-4A and J-4B	J-5
16. Size of mounting bolts, inches.....	$\frac{3}{8}$	$\frac{3}{8}$
17. Overall dimensions:		
Overall length of engine Aero-marine starter.....	39 $\frac{7}{8}$	
Eclipse starter, inches.....	39 $\frac{3}{8}$	40 $\frac{5}{32}$
Overall diameter outside of rocker arms, inches.....	43 $\frac{3}{4}$	45
Ignition		
18. Magneto type.....	Scintilla	Scintilla
19. Direction of rotation of magnetos (looking at drive coupling end)...	Both counter-clockwise	Both counter-clockwise
20. Magneto speed.....	1 $\frac{1}{8}$ times crankshaft	1 $\frac{1}{8}$ times crankshaft
21. Magneto breaker-point gap:		
Splitdorf magneto.....	0.020–0.024 in.	
Scintilla magneto, inches.....	0.012	0.012
22. Spark-plug point gap, inches.....	(A. C.) 0.020–0.025	(B. G.) 0.015
23. Spark occurs crankshaft degrees before top dead center.....	30°	30°
Valves and Timing (With hot or running tappet clearance)		
24. Intake closes.....	60° A. B. C.	60° A. B. C.
Intake opens.....	8° B. T. C.	8° B. T. C.
25. Exhaust opens.....	60° B. B. C.	60° B. B. C.
Exhaust closes.....	8° A. T. C.	8° A. T. C.
26. Exhaust remains open, crankshaft degrees.....	248°	248°
27. Intake remains open, crankshaft degrees.....	248°	248°
28. Valve lift, inches.....	$\frac{7}{16}$	$\frac{1}{2}$
29. Valve-tappet clearance (both valves)		
Hot or running clearance, inches	0.060	0.060
Cold clearance, inches.....	0.010	0.040
Fuel System	Stromberg	Stromberg
30. Carbureter type.....	NA-U5G	NA-T4

GENERAL SPECIFICATIONS FOR J-4A, J-4B, AND J-5 ENGINES.—(Continued)

Ignition	J-4A and J-4B	J-5
31. Carbureter settings:		
Venturi (choke), inches.....	1 $\frac{3}{4}$	1 $\frac{7}{16}$
Metering jet.....	No. 43	No. 51
Accelerating well bore, inches		
(Upper).....	7 $\frac{3}{32}$	$\frac{1}{4}$
(Lower).....	No. 14	No. 14
Main-jet air bleed.....	No. 53	No. 55
Idle metering jet.....	No. 58	No. 60
Idle air bleed.....	No. 50	No. 40
Float level below parting line, inches.....	1 $\frac{1}{2}$	1 $\frac{3}{16}$
32. Guaranteed fuel consumption, pounds per horsepower hour at 200 horsepower and normal r.p.m.....	0.60	0.53
33. Correct pressure on fuel supply, pounds per square inch.....	4	4
Lubricating System		
34. Guaranteed oil consumption, pounds per horsepower-hour not over.....	0.025	0.035
35. Correct oil pressure, pounds per square inch at normal r.p.m. at recommended oil temperature...	60	60
36. Quantity of oil circulated per min- ute at normal pressure and tem- perature, pounds per minute....	27	27
37. Minimum safe quantity of oil in whole system, gallons.....	2	2
38. Maximum permissible outlet tem- perature of oil under worst con- ditions ¹	180° F.	180° F.
39. Desired maximum oil outlet tem- perature in normal operation ¹ ...	120° F.	120° F.
40. Speed of oil pump.....	Crankshaft speed	Crankshaft speed
41. Direction of rotation of oil pump (looking at driven end of shaft) ..	Counter- clockwise	Counter- clockwise

GENERAL SPECIFICATIONS FOR J-4A, J-4B, AND J-5 ENGINES.—(Continued)

Ignition		J-4A and J-4B	J-5
42. Hose connections required between engine and lubricating system:			
Inlet	{ inside diameter, inches..	$\frac{3}{4}$	$\frac{3}{4}$
and			
outlet	number of pieces.....	2	2
43. Valve-spring loading (plus or minus 10 per cent):			

	Valve closed		Valve open	
	Length, inches	Load, pounds	Length, inches	Load, pounds
J-5:				
Inner.....	$1\frac{9}{32}$	8.4	$1\frac{3}{32}$	13
Intermediate.....	$1\frac{9}{32}$	13.3	$1\frac{3}{32}$	22.4
Outer.....	$1\frac{9}{32}$	20.1	$1\frac{3}{32}$	33.6
J-4B:				
Inner.....	$1\frac{3}{4}$	15.1	$1\frac{5}{16}$	24.4
Outer.....	$1\frac{3}{4}$	22.2	$1\frac{5}{16}$	37.9

¹ Inlet temperature of oil will be approximately 10° F. lower.

Cylinders.—An aluminum-alloy head and barrel with cooling fins cast integrally is screwed and shrunk onto a steel cylinder sleeve forged with a hold-down flange. Eight studs passing through this flange are used to fasten each cylinder unit to the crankcase. The cylinder head contains two ports, the axes of which are at right angles to each other. To the port facing aft is attached the induction pipe, and to the port projecting in the plane of the cylinders is fastened the exhaust stack. Bosses within the ports receive the valve guides which are pressed into position. The inlet-valve guides of all models are of bronze, while the exhausts are of bronze on the J-4 series and tungsten steel on the J-5. Valve seats of bronze are shrunk and expanded within the cylinder head. There are two spark plugs per cylinder. In Model J-4A cylinder, one bronze spark-plug bushing is screwed and pinned in the crown of the cylinder head forward of the inlet and exhaust ports. Another bushing of the same material is located in the rear side of the head with its axis

45 degrees to that of the inlet port. In Model J-4B cylinder, the two bronze spark-plug bushings are diametrically opposite in the sides of the combustion chamber and at an angle of 45 degrees to the crankshaft axis.

Model J-5 cylinder (Fig. 5) consists of a head with 13 fins cast in aluminum alloy screwed and shrunk onto a forged-steel barrel having 13 machined fins and the hold-down flange. The combustion chamber

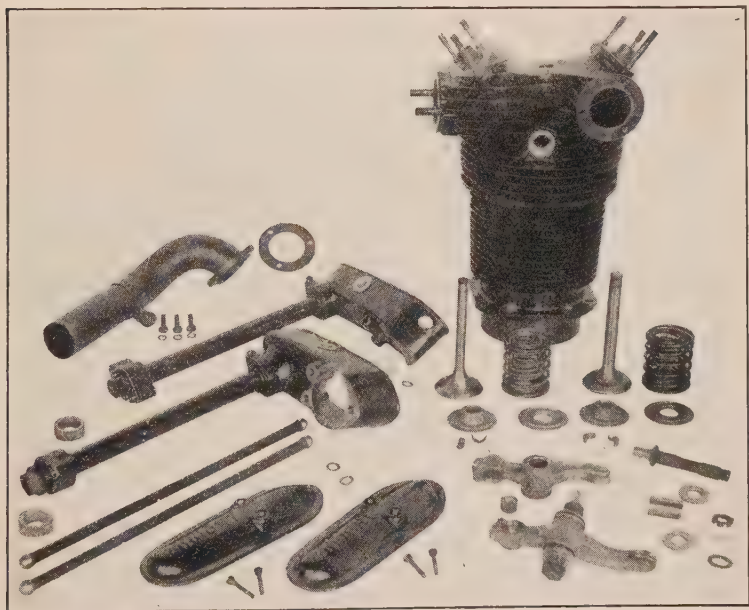


FIG. 5.—Whirlwind J-5 cylinder and parts.

of this cylinder is approximately hemispherical, with the valves inclined to the axis of the cylinder at angles of 35 degrees. The spark plugs are located similarly to those of the J-4B but at an angle of 10 degrees to the crankshaft axis. There are no bushings, the plug being screwed directly into the aluminum cylinder head.

Crankcase.—The crankcase assembly is built up of five aluminum-alloy castings held together by studs and nuts in generous quantity. The front section and nose plate include the thrust-bearing housing,

brackets for the magnetos, and the magneto and cam-driving gears. The intermediate section contains the cam valve-tappet mechanism and the front main crankshaft-bearing housing. The main section is provided with the cylinder pads and contains the rear main crankshaft bearing housing and the induction passages. The rear section contains drives for the fuel pump, oil pump, gun synchronizers, and tachometers. It also provides a mounting for the engine starter and a housing for the main oil strainer.

Crankshaft.—The crankshaft is of the single-throw, counter-balanced type machined from a chrome-nickel-steel forging and finished all over. It is hollow throughout its length and is used to distribute oil to all

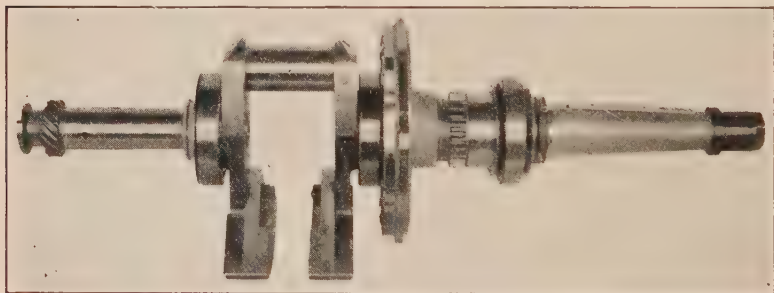


FIG. 6.—Wright Whirlwind crankshaft.

parts of the engine. The counter-weights are bolted to extensions of the crank cheeks. The shaft has four bearings—the ball thrust bearing, the two main roller bearings, and a plain bearing in the rear section where the oil is admitted. Figure 6 shows the shaft and those parts which are assembled with it in the engine. Starting from the rear end, these are the starter dog, accessories drive gear, retaining nut, oil slinger, rear bearing, front roller bearing, oil slinger (not visible), spacing ring (not visible), cam, cam-drive gear, spacer, oil slinger, thrust bearing, oil slinger, thrust-bearing nut, propeller-hub key, and propeller-hub inner nut.

Valve-operating Mechanism.—The cam is located in the intermediate section and consists of a hardened steel ring with eight lobes on the outside and an internal gear cut on the inside. This is riveted to an

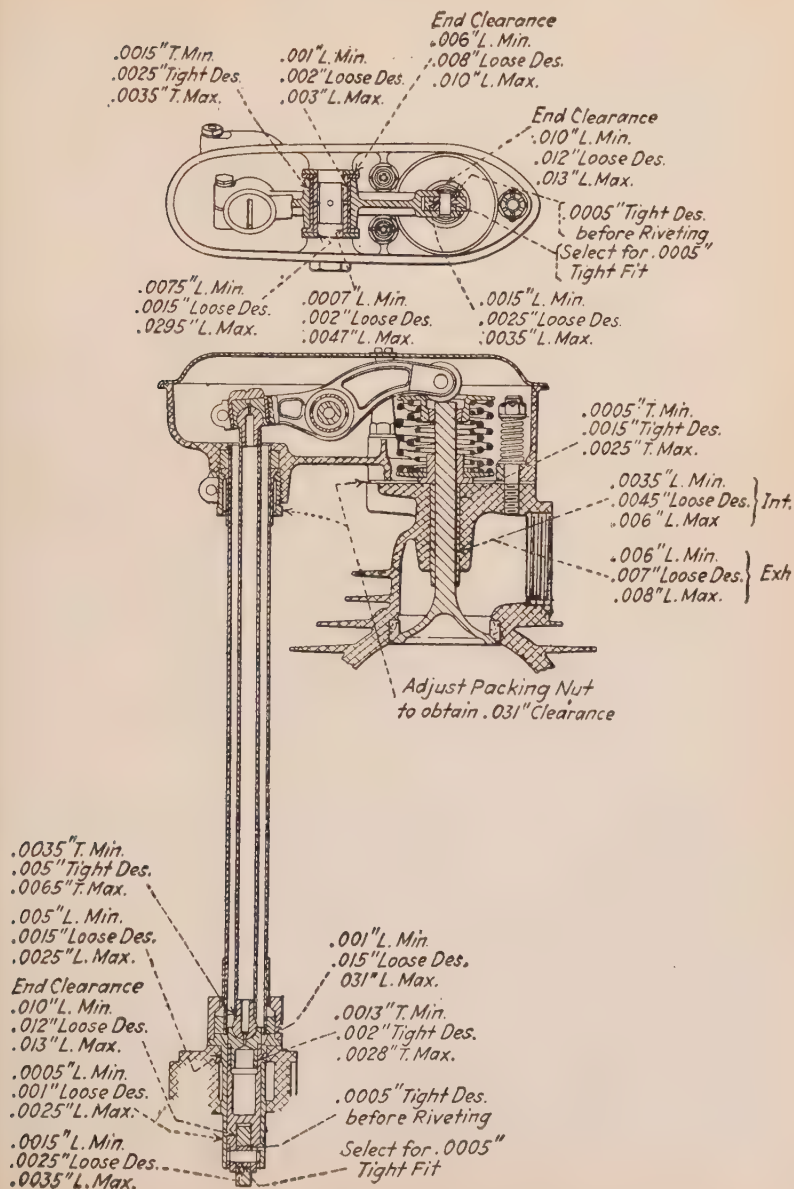
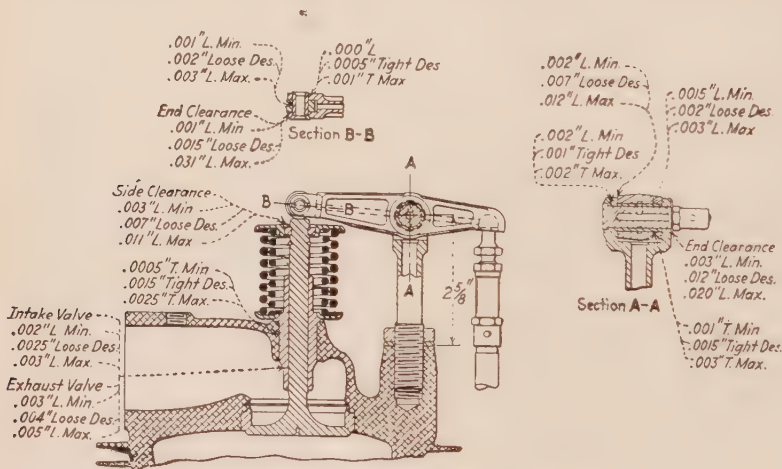


FIG. 7.—Limits chart J-5 valve mechanism.

aluminum hub riding on a steel sleeve on the crankshaft. The cam is rotated at one-eighth crankshaft speed in the opposite direction by a pinion on the cam and magneto drive shaft.

The camfollowers are of the conventional roller type and operate in cast-iron (J-4 series) or forged-steel bushings (J-5), which are a push fit in the intermediate section casting. The upper ends of the followers contain hardened steel sockets into which the lower push-rod balls fit, and in the lower ends are rollers which ride on the cam. Models J-4A



and J-4B push rods are equipped with a tappet-clearance adjustment on the upper end, while those of Model J-5 are plain pieces of specially heat-treated nickel-steel tubing with balls pressed into either end. The J-5 upper balls fit into hardened steel cups which are a loose fit inside the tappet-clearance adjusting screws. The J-4A and J-4B rocker arms are carried in forked supports of forged steel. The J-5 valve gear is semi-enclosed, the rocker-arm housing also forming the support for the rocker-arm pin. Tubular steel push-rod housings are fastened at one end to the intermediate section and to the rocker-arm housing at the other. Pressed aluminum covers are used on the rocker-arm housings (see Figs. 7 and 8).

Connecting Rods.—The connecting rods consist of one master rod and eight link rods machined from chrome-nickel-steel forgings. The master rod is provided with a steel-backed, babbitt-lined bearing, while the knuckle- and wristpin bushings of the link rods are of bronze. Figure 9 shows the relationship between the parts.

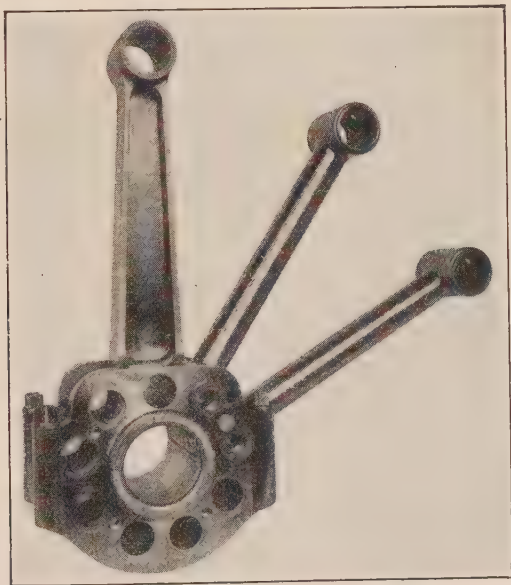


FIG. 9.—Master connecting rod and link rods.

Pistons.—The pistons are of the conventional type cast in aluminum alloy. The inside of the head is heavily ribbed to obtain increased strength and to improve the cooling. There are two compression rings and one oil-scraper ring above the pin and one compression ring at the bottom of the skirt. A groove around the piston just below the scraper ring and holes drilled through the wall return the oil to the inside of the crankcase. The piston skirt is provided with a series of shallow oil grooves to improve lubrication.

Wristpins.—The wristpins are of generous size machined from alloy-steel stock and oil hardened. Aluminum-alloy plugs in the ends prevent scoring of the cylinder walls.

Valves.—On Models J-4A and J-4B the intake valves are of tungsten steel and are of the mushroom type. The exhaust valves are of the tulip type in Silchrome steel.

Model J-5 intake and exhaust valves are both of the tulip type and are of low-tungsten and cobalt-chrome (or high-tungsten) steels, respec-

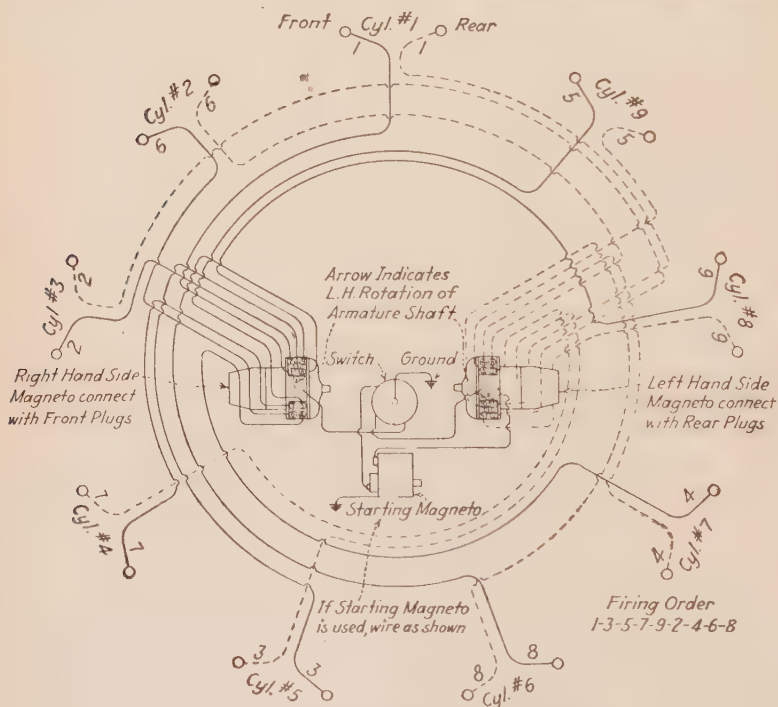


FIG. 10.—Wiring diagram J-4B and J-5.

tively. The exhaust valves on Model J-5 are salt filled and sealed at the top with hardened plugs.

Valve Seats.—The valve seats are annular rings of aluminum bronze of rectangular cross-section. They are first shrunk into the cylinder head, and then the small shoulder provided at the top is rolled over into an annular recess in the valve port.

Valve Springs.—The valve springs on Models J-4A and J-4B consist of two concentric, helical coils of round steel wire per valve. Model J-5 has three springs per valve.

Ignition.—Ignition is furnished by two Scintilla AG-9D magnetos mounted on the front section of the crankcase. The right-hand magneto fires the front spark plugs (top plugs J-4A), and the left-hand magneto fires the rear spark plugs. The wiring is of the heavily insulated high-tension type and is largely enclosed in metal manifolds. Figure 10 shows wiring diagram.

Fuel Pump.—The Wright fuel pump is of the Viking internal-gear type. This consists of an engine-driven internal-gear meshing with a gear which rides on a pin fixed in the pump cover. A crescent-shaped boss on the cover fills the space between the two gears opposite the point of contact. Fuel is taken in at the connection on the side near the pressure relief valve, carried around in the gear 270 degrees and discharged through the connection near the bypass relief valve. The pressure relief valve, which is covered by a domed cap, can be adjusted to give any desired pressure in the discharge line. It consists of a plunger valve, a spring, an adjusting screw, and a locknut. The excess fuel coming through this valve comes out of the connection between the bypass relief valve and the mounting flange. (This connection can also be made at the opposite end of the same passage.) A bypass valve between the inlet and outlet passages enables the operator to pump fuel to the carbureter with the hand pump without forcing it through the gears. It is covered by a flat brass cap.

Carbureter.—The Stromberg NA-U5G carbureter is used on Models J-4A and J-4B. It is of the double-barreled type and equipped with a mechanical economizer. The NA-T4 three-barreled carbureter is used on the J-5.

Induction System.—The carbureter is fastened to an oil-jacketed manifold at the bottom of the crankcase main section. In the case of the double-barreled carbureter, this manifold splits the two streams of vaporized fuel into three, and for the three-barreled carbureter, it provides three unbroken passages.

The rear of the crankcase main section contains three annular rings each of which supplies fuel to three cylinders through steel intake pipes. The fuel is fed into the three rings through the branches of the manifold described above. As observed from the rear of the engine, the left-hand

passage supplies cylinders 2, 5, and 8, the middle passage supplies cylinders 1, 4, and 7, and the right-hand passage supplies cylinders 3, 6, and 9.

Lubrication System.—The lubrication system is of the full-pressure type except for the cylinder walls, wristpins, and accessories drive gears, which are lubricated by splash. Oil is carried in an external tank, not furnished with the engine. The oil is drawn from the bottom of the tank by the pressure pump and delivered to the annular groove around the rear (plain) crankshaft bearing, at which point it enters the crankshaft. The crankshaft is drilled to supply oil to the connecting-rod crank-pin bearing, to the cam bearing, and to passages near the front end of the crankcase which lead to the magneto-drive bearings. Holes through the connecting-rod bearing shell convey the oil into passages which carry it into the knuckle pins and thence to the knuckle-pin bearings. The various gears, shafts, and bearings in the crankcase, rear section, are lubricated by oil which sprays from the rear crankshaft bearing. Passages in the front section lead oil to the cam-drive shaft and magneto shaft bearings, the spray from these and the cam bearing being utilized to lubricate the gears and valve tappets. Cylinders, pistons, and piston pins are lubricated by spray from the crankpin bearing. Rocker-arm pins are provided with Alemite grease-gun connections.

Accessories.—The crankcase rear section is fastened to the rear wall of the crankcase main section by five studs and two bolts. It contains the oil pump, oil strainers, oil-pressure relief valve, fuel pump, gun synchronizers, and the starter mounting pad. Figure 11 shows the rear section completely disassembled, with the parts arranged to show their relationship to the assembly.

Hand Starter.—The crankcase rear section is provided with a standard army and navy starter pad. The Wright hand starter is of the worm type, with a gear ratio of 6:1. (It is also supplied with a 15:1 ratio for larger engines.) Running through the starter is a splined shaft, one end of which fits into the engine crankshaft. The other end holds a spring-loaded clutch and a bronze housing carrying on one end the starter worm gear, which engages with a worm on the hand crankshaft. The starting magneto, which is an integral part of the device, is also driven by the starting crank through gears.

In starting, the worm is brought into contact with the worm wheel by pushing on the small rod beside the starting hand crank. Turning

the crank then brings the worm into full engagement, and further turning rotates the engine crankshaft. When the engine starts, the worm is thrown out of engagement and slides along the cranking shaft to an inoperative position. The disengagement of the worm does not throw the starting magneto out of gear, so it can be kept in operation by turning on the hand crank until the engine has picked up enough speed to fire regularly on the running magnetos. The starting magneto is designed to operate in connection with a "trailing brush" on the running magneto which gives a greatly retarded spark, reducing the possibility of a kick back to a minimum. Should this occur, however, the engine and starter are protected against damage by the clutch, which is designed to slip in such an emergency. An external ratchet on the cranking shaft positively prevents the crank from turning backward.

All parts are thoroughly lubricated by pressure feed from the engine oiling system.

INSTALLATION IN THE AIRPLANE

Unpacking and Cleaning.—Wright Whirlwind engines are shipped from the factory in a sealed packing box with the following outside dimensions:

Height.....	46¾ inches
Width.....	52¼ inches
Length.....	54 inches
Displacement.....	76½ cubic feet

The shipping weight of the engine and box is:

J-4A.....	970 pounds
J-5.....	1,010 pounds

The following procedure should be adhered to in unpacking and cleaning a Wright Whirlwind engine:

1. Break the seals found under the metal protecting plates at the bottom of the box.
2. Remove the nuts on the four bolts found directly under the handles and lift the cover by the handles.
3. Remove the oil cloth from the engine.
4. Remove the spark plugs or dummy plugs and turn the engine over ten or twelve times to expel oil.

5. Replace the spark plugs. If they were in place in the engine when received, wash them in gasoline before replacing.

6. Remove the four lag screws securing the mounting plate to the bed timbers.

7. Lift the engine by passing a rope or cable under the front flange between the bolts of the propeller hub. If a hub is not supplied, it will be necessary to proceed in accordance with item 3, following.

8. Remove the mounting plate.

9. Remove the breather caps and screw in the lifting eyes. Lifting eyes are not furnished with the engine but may be purchased from the Wright Aeronautical Corporation.

10. Lower the engine on to a tilting stand and bolt in place securely.

11. Tilt stand until the crankshaft is horizontal.

12. Clean the engine with a gasoline spray.

13. Pass a cable through the lifting eyes and hoist the engine, removing it from the tilting stand.

If a tilting stand is not available, proceed as follows:

1. Perform operations 1 to 5 inclusive.

2. Tilt the base of the shipping box to an approximately vertical position and place a support under the propeller hub.

3. Using a piece of rope, make a loop around the base of cylinder 3 inside the push rods, pass both ends up over the hook of a suitable hoist and down around the base of cylinder 8. Another loop should be put around the hook and the propeller hub or crankshaft end, to provide proper balancing. Be sure that these ropes clear the rocker arms, spark plugs, and push rods.

4. Lift from the floor and remove the base of the engine box.

Installation in Airplane.—After the engine has been unpacked and cleaned, it will be ready for installation in the airplane. All burrs and sharp corners should be removed from the engine mount and the mounting flange. Care should be taken to see that the engine mount is flat and fits the mounting flange all around. Hoist the engine by the lifting eyes and carefully work the rear end through the mounting ring. Bolt to the mount securely with eight $\frac{3}{8}$ -inch diameter S.A.E. alloy-steel bolts and lock by some suitable means.

Lubrication System.—The suction pipe from the oil-jacketed carbureter manifold to the suction side of the scavenging pump should be installed. It is of the utmost importance to see that this pipe is free

from air leaks at the flanges. The flanges should be examined to see that they are square and free from dirt and that the gaskets are in good condition before bolting in place. *This is very important, as the engine will not function with air leaks in this line.*

The oil tank should, if possible, be located so that the oil level is above the oil pump. This will eliminate trouble with priming. The lines from the tank to the engine should be short, with as few bends as possible. Copper pipe of $\frac{3}{4}$ -inch diameter, heated and quenched after bending and well braced throughout its length to eliminate vibration, is recommended. The oil inlet and outlet connections on the engine will be found on the left-hand side of the rear section behind the mounting flange. These are fitted with nipples of the proper size, beaded for hose clamps.

The vent from the oil tank may be piped back into the engine crankcase with a $\frac{1}{2}$ -inch diameter pipe. A hole with a $\frac{3}{8}$ -inch pipe thread is provided on the left side of the rear section of the J-5 for this line. This prevents the spilling of oil from the oil tank during stunt maneuvers. The oil-pressure relief valve and oil strainer will also be found on the rear section and should be cleaned and adjusted as described later.

The oil-pressure line should be $\frac{1}{4}$ -inch copper tubing connecting the pressure outlet, found at the rear and bottom of the rear section, with the pressure gage on the instrument board. This tubing should be heated and quenched after bending and braced at frequent intervals to eliminate vibration. Brass fittings should be used on the ends of this line.

Ordinarily, it will not be necessary to install an oil cooler on Whirlwind engines, as the heat given to the oil is very small and is easily dissipated from the oil line and oil tank. Under certain extreme conditions, a cooler may be necessary, in which case, it should be inserted in the discharge line of the engine.

Cowling.—Where cowling is provided, it is desirable that some provision be made to regulate the cooling obtained by the engine. In cold weather, it is essential that the crankcase, carbureters, and the lower halves of the cylinder barrels be enclosed to lessen the dangers of cold oil. It is also advisable to lag all the external oil lines with some insulating material, especially the drain from the intermediate section to the sump. For operation in warm weather, provision should be made for a sufficiently increased flow of air over the crankcase and

cylinder barrels to insure adequate cooling of the engine. The lagging should be removed from the oil lines.

Fuel System.—Whirlwind engines are supplied with or without a fuel pump, at the option of the customer. If no fuel pump is supplied, the carbureter should be connected by a $\frac{3}{8}$ -inch line of copper tubing, heated and quenched after bending, to a gravity tank having at least a 20-inch head. If the fuel pump is supplied, the discharge from the pump is connected by $\frac{3}{8}$ -inch copper tubing to the carbureter, the pressure relief is returned to the supply tank, and the intake line is taken from the bottom of the supply tank. The fuel lines should be as simple as possible and free from vertical bends in which air pockets can form. The lift from the tank to the pump should not be more than 3 feet. It will be necessary to prime the engine fuel pump with a suitable hand pump. The engine fuel pump is fitted with a bypass valve which allows the fuel from the priming pump to flow around the pump gear into the discharge line to the carbureter, thus eliminating the necessity for a complicated valve system. To adjust the pressure in the carbureter feed line, remove the domed cap from the relief valve, loosen the locknut, and screw in or out on the adjusting screw to raise or lower the pressure.

Magneto Wiring.—The top connections "P" of the magnetos should be connected to the points on the grounding switch marked "R Mag" and "L Mag" with insulated ignition wire. The point marked "Grd" on the switch should be connected to the engine crankcase. These wires should all be clipped at suitable points to prevent them from chafing or burning on the engine. This is most important, as the proper functioning of the engine depends on the contacts made through these wires. If an inertia or electric starter is used, a booster magneto is not essential but may be of considerable aid in cold weather. The booster magneto can be mounted in the cockpit, in which case, the high-tension lead will be connected to the terminal "H" on the top of either magneto. The ground wire from the booster magneto should be connected to the terminal marked "Start" on the switch. If the booster is used from the ground, the high-tension lead should be inserted in the terminal marked "H" on one of the running magnetos, and the body of the booster magneto should be grounded on the engine. In this case, the connection can be pulled out as soon as the engine starts and the magneto kept on the ground.

Spark Advance Lever.—The spark-control levers on the magnetos are connected by rods, ball joints, and levers to a cross-shaft running through the rear part of the crankcase. The left end of this shaft is provided with a lever to which the control rod is to be attached. The movement of this lever is 72 degrees, the radius is $1\frac{7}{16}$ inches, and the hole in the end is drilled for a $\frac{3}{16}$ -inch pin.

Carbureter J-4B.—The carbureter is adjusted at the factory to give the proper fuel consumption when mounted on the engine facing the rear with no air scoop. If an air scoop is added or the carbureter is faced forward, the fuel characteristics of the engine will be changed and a further adjustment may be necessary. It is therefore recommended that the carbureter installation be left as received. In case a change is necessary, the service department of the company should be consulted.

The controls on the J-4B engine are on opposite sides of the carbureter—the throttle on the right and the mixture-control lever on the left. The throttle lever can be adjusted to any position by removing the cotter pin and nut on the end of the throttle shaft and moving the lever on the serrations to the desired angle, then replacing the nut and cotter pin. Do not draw up this nut too tightly, as it will shear the shoulder on the throttle shaft and cause it to bind. The throttle lever cannot be moved from one side of the carbureter to the other. It has a radius of $1\frac{7}{8}$ inches and a travel of 70 degrees between full open and full closed. Both throttle and mixture levers are drilled to 0.218 inch the throttle lever being $\frac{1}{4}$ inch thick and the mixture lever $\frac{5}{32}$ inch thick. Clockwise rotation of the lever opens the throttle, and counter-clockwise closes it. The mixture control swings through an angle of 90 degrees on a $1\frac{1}{4}$ -inch radius. Clockwise rotation of the lever is full rich and counter-clockwise full lean. The mixture control operates from 45 degrees below horizontal to 45 degrees above horizontal. This movement can be changed only by fitting a special lever. In fitting a special lever, care should be taken to see that the mixture-control valve is not shifted from its proper position.

The fuel-pressure line connection should be made at the drain hole in the wall of the carbureter strainer chamber. When received, this hole will be stopped with a plug stamped "Drain."

Carbureter J-5.—The float chamber of the J-5 carbureter is so arranged that the gasoline will approximate normal head when the ship is thrown from the catapult or goes through stunt maneuvers.

It is therefore inadvisable to turn the carbureter around, as this will upset these conditions. The throttle and mixture-control levers of the NA-T4 carbureter are both on the right-hand side, and neither can be shifted to the other side. The throttle lever, as on the NA-U5G carbureter, can be adjusted to any desired angular position and has a movement of 70 degrees between full open and full closed. The mixture control lever is in the full-rich position at 34 degrees aft of the vertical and full-lean at 21 degrees forward of the vertical. The radius of both levers is $1\frac{3}{8}$ inches and both are drilled for a $\frac{3}{16}$ -inch pin. The throttle lever is 0.248 inch thick and the mixture-control lever is 0.186 inch thick.

The fuel-pressure gage-line connection should be made at the drain hole in the wall of the carbureter strainer chamber. When received, this hole will be stopped with a plug stamped "Drain."

Tachometer Drive Connection.—The two tachometer drive connections will be found on top of the oil pump on the left-hand side of the rear section. These are of the United States Air Corps standard form with a $\frac{7}{8}$ -inch, 18 thread. They rotate at one-half crankshaft speed in a counter-clockwise direction, as viewed from the open end.

Starter.—Several types of starters are supplied on J-4B and J-5 engines, as desired by the customer. On all starters, a hand crank is required, which fits over a shaft and drives through a pin. In most cases, the hand crank is supplied with the starter, but it may be necessary to change its length to suit various installations. An outside bearing in line with the starter shaft will be necessary. This bearing should be rigid and have sufficient clearance to allow for a slight misalignment of the hand crank and starter shaft. With the inertia starters, a push-pull control is necessary to operate the engaging dog. This control can be lead to the pilot's seat or brought out near the crank. In order to disengage the clutch, it is necessary to push the control if the engine fails to start. A rod mechanism is therefore essential. The same installation is required with the worm type of starter. If, for any reason, the starter dog is removed and not replaced, dummy parts will be required in the crankshaft to seal it against engine oil pressure.

Mounting the Propeller.—The propeller should be designed to allow the engine to turn approximately rated speed at full throttle when the ship is in level flight. Other speeds are undesirable, as low speed holds down the power of the engine, causes excessive torque vibration,

and increases the tendency to detonate, while high speed subjects the engine to strains which will shorten its life.

The propeller should be installed on the hub with the dowel in the line of the blades. In this position, the propeller blade marks top and bottom center cylinder 1. With the hub placed on an arbor, the propeller should be set on parallels to check the balance. The propeller should also be checked for track, *i.e.*, the following of one blade in the plane of the others. This can be done most easily in the ship by establishing a point on the plane close to the propeller tip and checking the distance to each blade as it passes this point. No propeller which is out of track or balance should be used.

When mounting the propeller, the taper and threads on the crankshaft should first be cleaned with gasoline and blown off with an air hose, if one is available. The same treatment should be given the bore of the propeller hub and the crankshaft nuts. The crankshaft should then be coated with engine oil or graphited 600W, and the propeller hub pushed on. The inner nut should be screwed onto the crankshaft until it is home. It is advisable to hit the propeller hub wrench three or four times with a lead hammer to be sure that this nut is tight. The outer nut should then be screwed into the hub, and the same procedure followed. Be sure that these nuts are clean and well oiled before installing. A hole in the inner nut must register with a similar hole in the outer nut to take a cotter pin for locking. There are 12 holes in the inner nut and 2 holes spaced 45 degrees apart in the outer nut; so it is a fairly easy matter to bring the nuts together for a cotter pin.

Turn the engine over a few times by hand to make sure that the propeller has ample clearance at all points.

INSTRUCTIONS FOR STARTING AND NORMAL OPERATION

Before starting the engine for the first time, the following procedure should be observed:

1. Check over all nuts and bolts both on the engine and the mount and see that they are tight and properly locked.
2. Check the propeller-hub nuts to be sure that they are tight and cotted.
3. Lubricate the valve gear with Alemite gun, using 600W oil.

4. Fill the oil tank with an ample quantity of oil for the run (minimum quantity 2 gallons) and see that all lines are open.

5. Fill the gasoline tank with the proper grade of gasoline.

6. Operate the throttle and mixture controls and inspect the levers on the carbureter to make sure that they hit the stop on both ends of the travel without restriction.

7. Operate the spark-advance control and inspect for full operation of the lever.

8. See that the tachometer and pressure gage are properly connected and that the oil-temperature thermometer bulb is in place.

9. Turn the engine over by hand to see that everything is clear.

10. See that the priming line and pump are properly connected and in working order.

11. Open the cocks in the gas line and operate the hand pump if supplied. See that gasoline is supplied to the carbureter and that all lines are tight. See that the carbureter does not drip gas.

12. See that ground wires are connected to the magnetos.

Starting.—Having completed the prestarting inspection, the engine is ready to start and should be handled as follows:

1. It is advisable before starting an engine to turn the engine over two complete revolutions, with the ignition switch off. This procedure is for the purpose of making certain that none of the cylinders have filled up with gasoline, due to a leaky primer line.

Whenever the primer is not in use, the shut-off on the priming line should be closed.

2. Give the engine several strokes of the priming pump. Experience is necessary to determine the proper amount of prime for each engine. About five or six strokes of the pump are usually necessary. Excessive priming has a tendency to wash the oil off the cylinder walls and cause scoring or seizing of the sleeves and pistons.

In cold weather, the engine requires more priming than in warm weather.

A hot engine does not ordinarily require priming.

3. Turn the engine over a number of times with the throttle closed to suck the gas into the cylinders.

4. Set the throttle to approximately one-eighth open and the mixture to full rich. Easier starting will be obtained with spark control at approximately full advance.

5. Operate the starter and allow the engine to turn over a full revolution. Then turn the ignition switch to the start position and operate the booster, if one is being used.

6. If the engine fails to start after several attempts, prime again and repeat. If the engine is overprimed, the throttle should be opened wide and the engine turned backward several revolutions by hand. Be sure that the ignition switch is off.

7. In extreme cold weather, the oil should be heated before filling the oil tank.

If the engine fails to start after a reasonable number of attempts, consult the notes on troubles to ascertain possible cause.

Ground Test.—When the engine starts, the spark should be advanced, the throttle pulled back to 600 or 800 r.p.m., and the gage watched for oil pressure. If the oil pressure fails to rise within 1 minute, the engine should be shut down and an investigation made (see p. 167). After the gage indicates the oil pressure, the engine should be run at 600 to 800 r.p.m. for 2 minutes or more and the throttle then opened to 1,000 r.p.m., where it should be held until the oil-outlet temperature starts to rise. The speed may then be increased slowly to full throttle. The mixture control should be leaned out until the engine is turning its maximum r.p.m. This may occur in the full-rich position. Observe the r.p.m., oil pressure, and oil temperature. With the mixture control set for maximum r.p.m., check the functioning of the engine when running on one magneto at a time. If the values observed are normal and the speed does not drop more than 75 r.p.m. on each magneto, the engine is ready to fly. It should be remembered that it receives very poor cooling while on the ground, and prolonged running at full throttle should be avoided.

Flight.—The instruments should be noted at frequent intervals to see that the power plant is functioning properly. The engine should be operated to keep within the following limits:

Oil pressure 50 to 75 pounds per square inch

Outlet oil temperature not over 180° F. (82° C.)

Fuel pressure 2 to 4 pounds per square inch.

If the oil pressure falls below 35 pounds, an immediate landing should be made and the cause of the trouble located and removed (see Troubles, p. 167). It is not so serious when the oil pressure exceeds

the high limit, but it should be corrected at the end of the flight. This can generally be done by adjusting the relief valve.

High oil temperature, when not caused by atmospheric conditions, may be a sign of trouble in the engine. If the outlet oil temperature rises above 180° F., a landing should be made as soon as possible and the cause of the rise in temperature determined and corrected (see p. 168).

Landing.—Because of the faster heating and cooling rate of air-cooled engines, a hot engine should never be shut down rapidly, except in emergencies, as this is almost sure to warp the valves. After a plane has landed and taxied to the line, the spark should be retarded, the throttle slowly closed to 600–700 r.p.m., and the gasoline supply shut off. The engine should be allowed to run this way until the fuel supply fails. If this is done regularly, the time between overhauls will be greatly increased.

ENGINE TROUBLES

Determining the cause of engine trouble is, at times, rather involved, on account of the number of sources to which a given symptom may be attributed. The best method of trouble shooting is first to decide on the possible causes and then to eliminate them one by one, starting with the most likely.

This table of the commonest troubles and their causes is submitted to the service men with the object of reducing wasted time and increasing the reliability of the Whirlwind engine.

If the engine fails to start, it may be due to any one of the following causes:

1. *Lack of Fuel.*—Examine the fuel supply, shut-off cocks, traps, strainers, and hose connections.
2. *Underpriming or Overpriming.*—See instructions on starting.
3. *Booster Magneto Defective.*—Examine and test the starting magneto.
4. *Throttle Opening Incorrect.*—The throttle should be approximately one-eighth open while starting.
5. *Defective Ignition Wire.*—Examine the ignition wiring for wear, breaks, and incorrect connections.
6. *Dirty Spark Plugs.*—Check the spark plugs for proper functioning. Clean and set gaps (B. G., 0.015 inch; A. C., 0.020 to 0.025 inch).
7. *Incorrect Valve-tappet Clearance.*—Check the valve-tappet clearance.
8. *Incorrect Timing.*—Check the valve and ignition timing.

9. *Water in Carbureter*.—Remove a plug from the bottom of the carbureter and drain out the gas and water.

10. *Cold Oil*.—With the ignition switches off, turn the engine over by hand. If it is very stiff, it will be necessary to heat the oil before starting.

11. *Magneto Breaker Points*.—See that the magneto breaker points are clean and have the proper gap (0.012 inch). Test the spark delivered by the magneto.

12. *Miscellaneous*.—Examine the engine carefully for unusual conditions, turning over slowly by hand.

Low oil pressure or none at all may be caused by the following:

1. *Lack of Priming*.—Disconnect the oil-suction line and fill the pump with oil. Turn the engine over by hand until the oil is sucked into the pump. Check the oil supply.

2. *Leak in Suction Lines*.—Examine the oil-suction lines for air leaks.

3. *Dirt in Oil Screen*.—Remove and clean the oil strainer.

4. *Oil Pressure Relief Valve*.—Examine the oil pressure relief valve and spring for proper seating or breakage.

5. *Gun Synchronizers or Starter Dog Removed*.—The gun synchronizers are on the main oil line and, if removed, should be replaced with dummy parts. The same is true of the starter dog.

6. *Crankshaft Plug Out*.—Remove a cylinder and examine the crankshaft plugs.

7. *Excessive Bearing Clearance*.—A bearing may be worn enough to cut down the pressure, in which case an overhaul will be necessary.

Crankcase filling with oil is usually caused by lack of priming in the discharge pump. Disconnect the main discharge line from the engine and put on a 2-foot length of garden hose. Feed oil into this hose while turning in engine backward until a quart or so has been sucked in. Check oil pumps, strainers, and lines for failures or stoppages.

Engine runs unevenly and does not come up to power. The full throttle speed of the engine will vary 75 to 100 r.p.m. under different atmospheric conditions. It will also vary considerably with the condition of the propeller. The engine, therefore, should not be considered low on power unless the drop in speed is excessive under similar conditions.

Low power and uneven running may be traced to any of the following causes:

1. *Rich or Lean Mixture.*—Make sure that the mixture control lever is in the best position.

2. *Leaks in Induction System.*—Examine the intake pipes for cracks and for leaks at the cylinder and crankcase connections. Examine the carbureter and manifold flanges for tightness. Examine the pipe plugs in the cylinder inlet ports to see that they are all tight.

3. *Spark Plugs.*—See that all the spark plugs are clean and that they have the proper clearance. *

4. *Valve and Valve-gear Trouble.*—Check the valve-tappet clearance, springs, washers, rocker arms, and push rods. Be sure that the push rods on J-4 series engines have not been interchanged. The camfollowers nearer the propeller operate the exhaust valves. See that the valves are not sticking.

5. *Poor Fuel.*—Make sure that the fuel being used is a good grade of domestic aviation gasoline and that it flows freely to the carbureter.

6. *Magneto Breaker Points.*—See that the magneto breaker points are clean and have the proper gap (0.012 inch). Check the operation of the magnetos.

7. *Engine Overheating.*—This may be caused by items 1, 2, 3, and 5, above. It is easily recognized by the fact that the engine will run at normal speed just after idling and will then slowly fall off. Continued running of an engine exhibiting this symptom is likely to cause considerable damage, so an investigation of the cause should be started immediately. Other causes are improper cowlings, excessive air temperature, thin oil, and insufficient oil cooling.

Excessive oil temperature may be caused by the following:

1. Insufficient oil cooling.
2. Insufficient oil supply. There should be at least 2 gallons of oil in the system.
3. Low-grade oil. See that the oil being used is up to specification.
4. Suction pump failing to scavenge oil properly from crankcase. Examine all oil lines for leaks.
5. Overheated bearing. If the trouble is not found after an investigation of items 1, 2, and 3, a bearing may be overheating, in which case, a disassembly will be necessary.

Carbureter Leaking.—Because of the fire hazard, the engine should not be run if the carbureter leaks gasoline excessively. This may be caused by

1. Leaky float.
2. Stuck float.
3. Poor seating of needle valve.
4. Wear of float fulcrum pin

In any case, the carbureter should be removed and checked over. If the float has been leaking, the gasoline should be removed, the hole soldered, and the float immersed in hot water to test for tightness. The needle-valve seat should be removed, the valve lapped in with fine compound, and the assembly tested for tightness and float level.

Cold-weather Cautions.—Under unusual weather conditions, it may become necessary to adopt some method of heating the air entering the carbureter to prevent the formation of ice at the chokes. Wright air heaters have been found very satisfactory for this purpose. Due to the wide variation in engine-installation requirements, these heaters are furnished without pipe connections.

In extremely cold weather, it will be necessary to preheat the oil before starting. A great deal of time can be saved by draining the oil from the tanks as soon as operations for the day are concluded and before the oil has cooled off. If left in the tank overnight, it may become so viscous as to require considerable time to drain off. In cold weather, it is also advisable to have some sort of lagging on all the external oil lines, especially the drain from the intermediate section to the sump. This will result in higher oil temperature at cruising speed and will decrease the danger of stoppage due to congealed oil. A layer of asbestos cord, shellacked and then wrapped with friction tape provides very good insulation. Lacking asbestos, several layers of ordinary packing cord can be used.

INSPECTION ROUTINE

In order to obtain maximum reliability and service from Whirlwind engines, a regular schedule of inspections and overhauls should be maintained. Serious failures very often arise from minor causes which a few minutes' inspection could have averted. The following schedule is suggested:

Starting Inspection.—See page 163.

Daily Inspection.—Every flying day, the following inspection should be made: Check all the cylinders, one at a time in firing order (1, 3, 5, 7, 9, 2, 4, 6, 8), as follows:

Models J-4A and J-4B:

1. Does the clearance between rocker roller and valve stem, on compression stroke, seem normal?
2. Are the rockers free on shafts and are the lock wires secure?
3. Are the rocker rollers free and are the lock wires secure?
4. Are the valves free in the guides?
5. Are the valve springs and valve-spring retainers intact?
6. Are the rocker-support locknuts tight and are the rocker rollers central on the valve stems?
7. Are the spark plugs tight?
8. Grease the rocker shaft with Alemite gun, using automobile transmission oil.
9. Oil the rocker rollers with engine oil.
10. Are the ignition terminals secure to the wires and plugs, and is the insulation on the wires intact?
11. Is the compression normal?

After all the cylinders have been checked, proceed as follows:

12. Are the carbureter and carbureter manifold tight at the securing flanges?
13. Are the fuel tanks filled?
14. Is the oil tank filled?
15. Are the magneto ground wires secure?
16. Are the throttle, mixture, and magneto controls free throughout their range?
17. What is the full-throttle r.p.m.?
18. Is the engine operation good on either magneto?
19. What are the oil pressure and temperature? Compare with the values given on page 165.
20. What is the gasoline pressure? (It should be 2 to 4 pounds per square inch.)

Model J-5:

The daily inspection of Model J-5 engine should include items 7, 8, and 10 to 20 inclusive.

After 20 Hours.—After every 20 hours of flight, the valve gear should be disassembled and inspected as follows:

1. Remove the push rods and examine the balls and ball sockets for wear.
2. Grease the sockets in rockers.

3. Thrust the lower ball ends of the push rods into a can of heavy grease and replace the rods in their proper sockets.
4. Make a complete inspection as outlined for each flying day.

Model J-5:

1. Remove the rocker-box covers and make a check of the amount of motion of the various parts. If the tappet clearance seems normal, it should not be disturbed. If any part seems to have too much motion, or if the tappet clearance is excessive, the rocker arm and push rod should be removed and the cause determined. Check the offending part against the maximum allowable clearance, and replace if this is exceeded or if, in the opinion of the operator, it seems advisable.

After the valve gear has been inspected, repaired, and reassembled, the following items should be checked (all J-series models except as noted):

1. On J-4 series engines, check the clearance between the rocker rollers and valve stems with a feeler and rest to 0.010. Be sure that the adjusting ball and the locknuts are tight.
2. Are the spark-plug points clean, and are the gaps set at the proper clearance (0.020 to 0.025 inch for A. C. plugs; 0.015 inch for B. G. plugs)?
3. Are the nuts on the inlet-pipe upper flanges tight?
4. Are the inlet-pipe packing nuts tight?
5. Are the cylinder hold-down nuts tight?
6. Are the fuel strainers clean?
7. Are the fuel lines and connections secure and free from leaks?
8. Is the lock on the gasoline-pump pressure-adjusting screw secure?
9. Are the oil strainers clean?
10. Drain the old oil from the tanks and lines and flush with kerosene until perfectly clean. (Do not use kerosene inside the engine.) Replace the lines and put 2 gallons of clean oil in the tank. Run the engine for 20 minutes and then drain out all the oil again. Replace the lines and fill the tank with clean oil. Great care should be taken to see that all the oil lines are replaced properly and that there are no air leaks. Small air leaks are apt to interfere seriously with the proper functioning of the lubricating system.
11. Oil tanks should be drained and filled with fresh oil.
12. See that the hand-turning gear is well lubricated.
13. Are the engine-mounting bolts tight?
14. Does each magneto get full advance when operated from the cockpit?

15. Are the magneto breaker points clean and the gaps set at 0.012 inch?

16. Are the magneto couplings in good condition?

17. Put four drops of medium machine oil into the rear magneto oil holes. Fill the front holes.

18. Are the propeller-hub locknuts and the propeller-hub bolts tight?

19. Check the clearance between the rear of the rocker boxes and the cylinder heads and make sure that it is 0.031 inch (engine cold). While this dimension should not vary, it is extremely important and should be checked carefully. Incorrect clearance is very apt to result in failure of the rocker-box studs.

It is advisable to run the engine at part throttle for at least $\frac{1}{4}$ to $\frac{1}{2}$ hour twice a week, in order to keep interior parts flushed with oil. This will prevent the vapor due to condensation in the crankcase from rusting the steel parts.

Complete Overhaul.—It is suggested that the compression, as noted in item 2 of the daily inspection, be checked very carefully on each cylinder. As soon as one is found to be low, the cylinder should be removed, the valves tested for leakage, and the piston rings checked for tension. The valves should be ground and the piston rings replaced when necessary (see p. 177). In this manner, the engine can be kept up to power and speed. It is sometimes very difficult to distinguish between a valve which is leaking and one which is being held open by a bit of dirt or carbon on the seat. The only way to check this out is to run the engine for several minutes and then try the compression again.

Experience with Whirlwind engines in service has indicated that the length of the period between overhauls is limited by the tendency of the lubricating system to fill up with sludge. This is composed of gums formed in burning the lubricating oil, carbon, lint, and substances taken into the engine through the carbureter or breathers. After 200 hours of service, the accumulation is likely to become severe enough to plug up one of the passages and result in the seizure of the bearing whose oil supply is cut off. It is therefore recommended that Whirlwind engines be given a complete overhaul after every 200 hours of service.

DISASSEMBLY AND INSPECTION

After removing the engine from the ship, mount it on a tilting stand, as shown in Fig. 11. If one of these is not available, a substitute

can be made by bolting the iron mounting plate from the shipping box to a suitable wooden stand, or the engine can be left mounted in the ship.

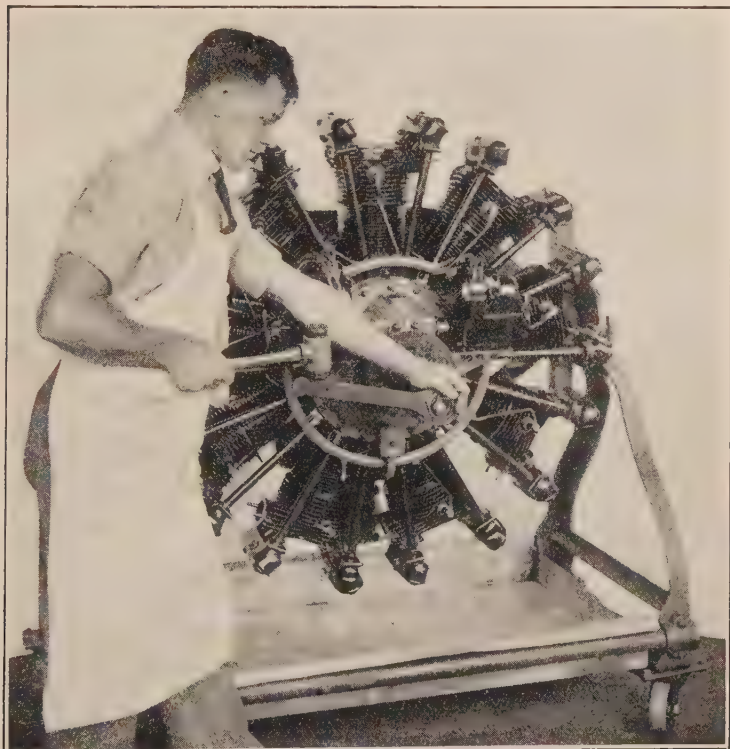


FIG. 11. —Removing propeller hub—first operation.

Disassemble the engine in accordance with the instructions found in the pages following. As each part is removed, it should be washed in gasoline and placed on the inspection bench. This bench should be located near the disassembly floor and where it will receive a good supply of light. A drop light is very handy for inspecting the cylinder bores and valve seats.

A service tool kit is furnished with each engine by the manufacturer. This contains tools sufficient for the general servicing of the engine and should be carried in the plane for use in emergencies. For completely

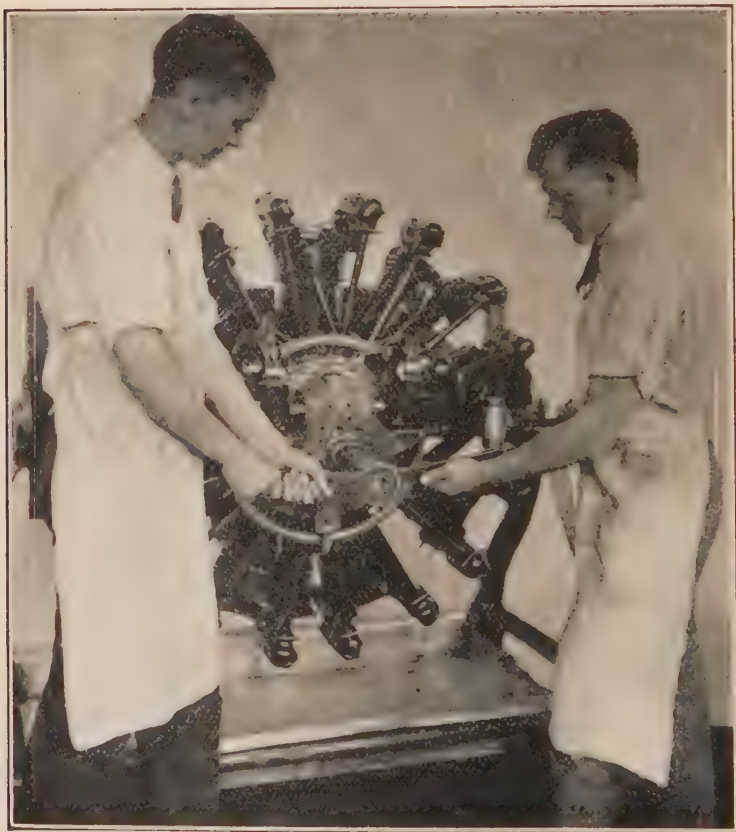


FIG. 12.—Removing propeller hub—third operation.

disassembling and reconditioning the engine, a number of special tools are absolutely essential. A repair depot handling any great number of engines should be equipped with a complete set.

The following instructions for disassembly are presented in as great detail as space permits.

1. Propeller Hub.—To remove the propeller hub, use wrenches which will be found in the service tool kit accompanying the engine. After removing the cotter pin, back off the outer or larger nut three full turns. Then back off the inner or smaller nut until it brings up against the outer nut. Holding the inner nut with the wrench, tighten up on the outer nut until the hub comes loose. It can then be pulled off by backing off on the inner nut. After removing the hub, the inner nut should be replaced on the crankshaft to avoid the possibility of damaging the threads. In loosening the nuts and the hub, it will be necessary to use considerable force; three or four blows with a lead hammer are usually required. (See Figs. 11 and 12.)

2. Ignition System.—After removing the wire terminals from the spark plugs, loosen the clips on the push-rod housings and intake pipes and free the ignition wires. It is not necessary to remove the clips. Remove the nuts, holding the wire manifold to the intermediate section. Remove the oil drain pipe running from the intermediate section to the oil sump. Disconnect the magneto-advance rods by unscrewing the pin from the magneto-advance lever. Withdraw the magneto-coupling cotter pin and disengage the coupling. Take out the four screws holding each magneto to the bracket. Free the magnetos from the dowels by striking lightly with the hand. Lift off the magneto and ignition-wiring assembly complete.

3. Carbureter.—If it has not already been done, remove the pipe running from the oil sump to the oil pump and the main fuel line. Remove the 12 nuts holding the manifold to the crankcase and withdraw the carbureter and the manifold.

4. Priming Lines.—The priming lines should be taken off by removing the stuffing nuts on the various fittings.

5. Cylinders.—When an engine is to be given a complete tear-down, the following rule should be strictly adhered to:

Cylinder 1 should be removed last. Failure to do this and lack of proper care will result in broken piston rings, broken pistons, and possibly injured cylinders.

The reasons for this warning and the proper precautions when it is necessary to make an exception to the rule are discussed later.

a. *Whirlwind J-5*.—Remove all the spark plugs and rotate the crankshaft until the piston of the cylinder to be removed is approximately on the top center. Remove the three screws holding the intake-pipe flanges together, loosen the intake-pipe packing nut in the crankcase, and remove the intake pipe. Remove the two nuts holding down the push-rod-housing packing flange, locknuts, and cylinder hold-down



FIG. 13.—Removing valve collar locks of J-5.



FIG. 14.—Same operation on J-4B.

flange nuts. Rock the cylinder gently from side to side and remove it by pulling it straight outward. Be careful that the piston does not swing over against either of the adjacent cylinders and that the push rods or rocker-arm cups do not fall out of the housings. As soon as a cylinder is removed, the piston should also be taken off, to avoid injury in subsequent operations.

To disassemble the valve gear, proceed as follows: Take out the two screws on top of the rocker-arm housing and remove the cover. Remove

the cotter pins and castellated nuts from the rocker-arm pins. These are on the outside ends of the pins. With a fiber or brass drift, tap the pins out of the housings toward the center of the cylinder.

For removing the valve springs and washers, some sort of jig to hold the valves in place is handy. This can easily be made from two pieces of wood, one as a base with the other piece (10 by 4 by 1 inch) nailed to it at right angles. The latter should be trimmed so that it will bear lightly on the valve heads when the cylinder is placed on it and the bottom of the sleeve rests on the base.

After placing the cylinder on the jig, place the valve-spring tool in position and slip a rod through the holes in the housing and the tool. Raising the handle of the tool, depress the valve spring until the split valve collar locks can be disengaged, as in Figs. 13 and 14. Take off the tool and remove the valve springs and washers. Unscrew the two nuts located inside each rocker box and remove the push-rod and rocker-arm housing assemblies. Do not disconnect the push-rod and rocker-arm housing assemblies unless necessary. Take off the wire lock rings located near the top of each valve stem. Holding the valves with one hand, take the cylinder off the jig and place it in a horizontal position on a bench. Remove the valves, taking care that they do not strike the cylinder walls on the way out.

b. Whirlwind J-4A and J-4B.—The order of procedure in taking off the cylinders of Models J-4A and J-4B is the same, but there is considerable difference in the detail.

After removing the spark plugs and taking off the intake pipes, the next step is to remove the push rods. This is best done by setting a monkey wrench to the proper size to slip over the rocker arm and with this compressing the valve spring. The push rod can then be lifted out. A convenient method of removing the rods is first to perform the operation on the cylinder which is on the compression stroke and then, rotating the crankshaft, follow the firing order (1, 3, 5, 7, 9, 2, 4, 6, 8) around the engine.

The cylinders can then be removed, proceeding as with Model J-5.

In disassembling the valve gear, the same sort of jig described for Model J-5 is necessary. Place the cylinder on the jig and insert the slotted end of the tool under the shoulders of the rocker-arm support. When the other end is pressed down, the end of the valve will project up through the round hole in the tool, and the locks can

be removed. Proceed as before in removing washers, springs, lock wires, and valves.

If the wristpins are a drive fit when cold, they should not be removed until the piston has been heated with hot water or steam. They can then be driven out with a fiber drift. Failure to heat the piston first may result in serious injury to the piston bosses and the wristpin plugs.

To remove the No. 1 or top cylinder without first removing the other cylinders, proceed as follows:

Set piston 1 on top dead center.

Remove the intake pipe, the two nuts holding down the push-rod packing flange, and the cylinder hold-down nuts.

Loosen the cylinder by rocking it gently back and forth, and pull it straight out. As soon as it is clear of the studs, slip the two rods into place between the master rod and the crankcase studs, one on either side. This will prevent the rod from tipping sideways and consequently keep the bottom rings on pistons 5 and 6 from coming up over the ends of the cylinder sleeves and breaking. The cylinder should be removed very carefully with a straight, steady pull.

The reassembly should be performed in the reverse order.

6. Nose Plate.—To remove the nose plate, take off the lock wire and, with a spanner wrench, unscrew the thrust-bearing nut. Then remove the nuts and washers and pull off the nose plate.

7. Crankcase Front Section.—The studs in the front of the J-5 crankcase main section extend through the intermediate and front sections holding the three together, while two sets of short studs perform the same function on the J-4B. Remove the nuts and pull off the front section. The front thrust bearing and the spacer on the crankshaft will come off with it. The section can be loosened by tapping lightly on the lower corners of the magneto brackets with a lead hammer.

The cam-drive gear should then be removed. This is keyed to the crankshaft and should be pulled.

The cam, cam spacer, and oil slinger can then be lifted off.

8. Intermediate Section.—After removing the nuts (J-4B), reach inside the crankcase with the lead hammer and tap lightly on the bottom of the intermediate section. This section can then be freed from the main section and the roller bearing.

9. Connecting Rods.—Cut all the lock wires and remove the cap-screws and knuckle-pin locks. Using the correct tool, pull out the

knuckle pins, removing each rod from the engine as its pin is withdrawn. In using this tool, first run the nut out to the head of the bolt and then screw the bolt down into the pin at least six full turns. Failure to do



FIG. 15.—Removing knuckle pins.

this may result in stripping the threads inside the pin. Run the loose nut down until it seats on the puller body and turn up on it with a wrench, withdrawing the pin. See Fig. 15.

10. Master Rod.—With the long-handled socket wrench, take out the four master-rod clamping screws. Tap on the master rod until the two parts separate and can be removed as in Fig. 16.

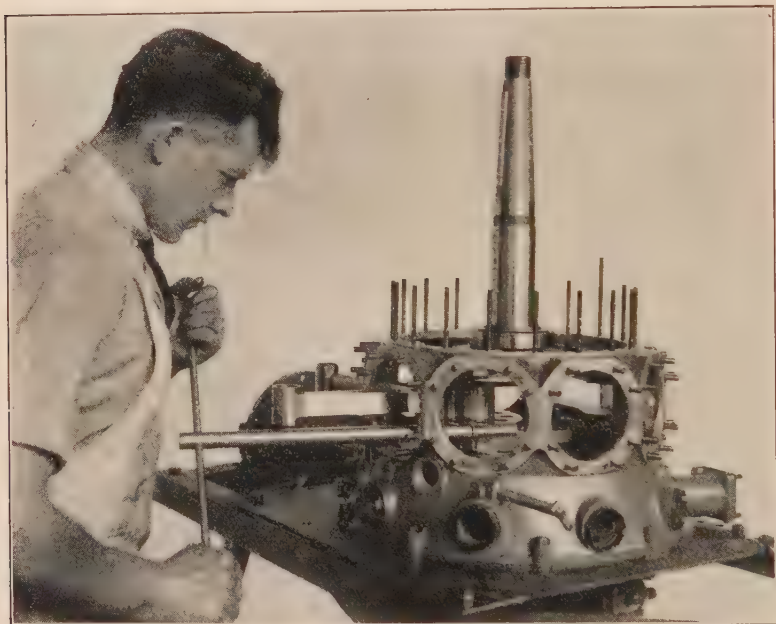


FIG. 16.—Removing master rod bolts.

11. Crankshaft.—Do not under any circumstances remove the crankshaft counterweights. If this is necessary, the crankshaft should be returned to the factory where the assembly can be properly balanced before using again.

Turn the motor over until the crankshaft is in a horizontal position and proceed as follows:

Unscrew the nuts and remove the starter. With a screwdriver, take out the screw which will be observed in the center of the starter dog. Pull out the starter dog. Pull out the accessories drive gear. The crankshaft will then be free and should be removed by pulling straight

out through the front of the crankcase. Take off the nuts holding the rear section to the crankcase, not forgetting the one at the bottom behind the oil strainer, and remove the rear section. See Fig. 17. The rear section is shown disassembled in Fig. 18.

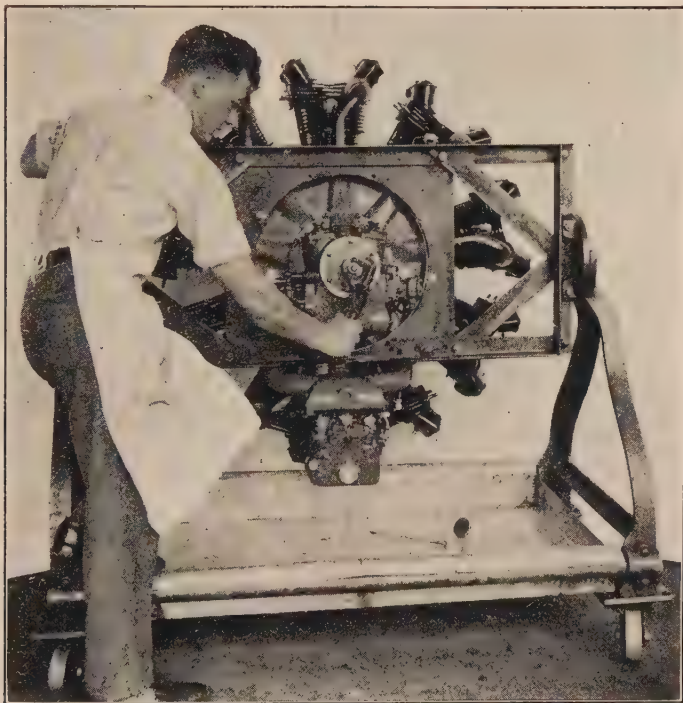


FIG. 17.—Removing crankshaft gear.

Remove the four nuts and pull off the fuel pump. Remove the four nuts and pull off the oil pump. Remove the four nuts on each and pull out the gun synchronizers.

To disassemble the fuel pump, remove the four castellated nuts and take off the cover. The two gears can then be removed and inspected for wear. Remove the two valves and see that the seats are in good condition.

To disassemble the oil pump, remove the four long bolts holding the four sections together. Remove the four screws holding the tachometer drive housing to the oil-pump cover. Examine all gears and housings for wear.

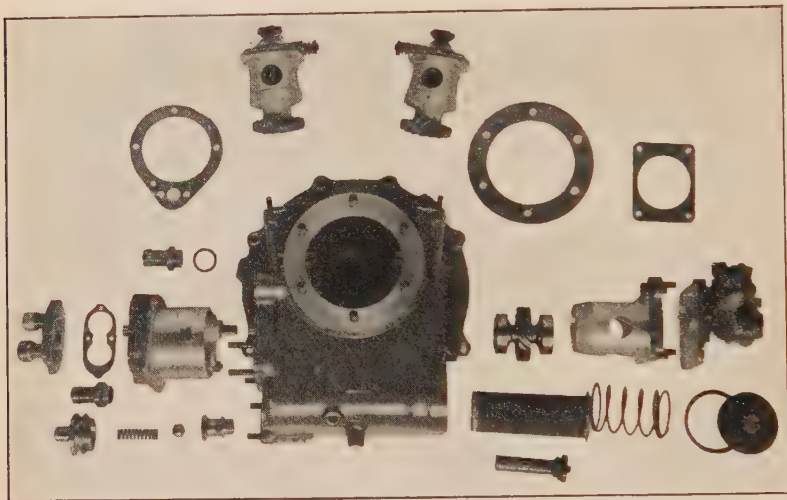


FIG. 18.—Rear section disassembled.

Inspection.—When the disassembly is complete and all the parts have been washed and laid on the bench, a very careful inspection should be made. This should consist of a general examination for signs of wear or failure and a check of all the wearing parts for the clearance.

The question of when a part should be replaced is one which cannot be decided by rule and must be left largely to the judgment of the inspector.

The piston rings should be checked for tension by measuring the gap between two corresponding points on the ends when the ring is free. If this is less than $\frac{1}{4}$ inch, the ring should be replaced.

The crankshaft main bearings and thrust bearing should be very carefully inspected for wear or deterioration. Clean each bearing thoroughly in gasoline and spin it, listening for any sound indicating uneven running. Hold the inner race in one hand and rotate the outer

race slowly with the other. As each ball passes, inspect for cracking, chipping, or corrosion. The same inspection should be made on the races. It is very difficult to make a good inspection of a roller bearing; the inspector should be guided largely by the smoothness of rotation and the amount of play. Roller bearings are built with some end play but should have very little radial play. Any bearing which is chipped, cracked, or corroded or which is excessively loose should be discarded.

If it is necessary to replace the master-rod main bearing or any of the articulated rod bearings, it is of the greatest importance that the reaming be done accurately and the proper alignment obtained. This necessitates the use of master and articulated rod-reaming fixture. If this tool is not available, the rod should be returned to the manufacturer for replacement of the part.

The spark plugs should all be taken apart and cleaned. Emery is a good conductor of electricity; so emery cloth should never be used for this purpose. Use garnet cloth, sandpaper, or a steel scraper. Set the gaps to 0.015 inch (B. G. plugs) by tapping on the outside end of the outer electrode with a center punch and hammer. If A. C. plugs are being used, they should be washed in gas, cleaned in an air blast, and have the gaps set at 0.020 inch to 0.025 inch.

Inspect the spark-plug threads in J-5 cylinders for signs of wear or picking up. The bronze bushings were omitted in this design with the idea of improving the running conditions of the spark plugs, and the tapped hole in the head substituted. Care must be taken in inserting and removing spark plugs to prevent stripping the aluminum threads. The plugs should be selected for smoothness and proper fit of the threads, and no plug which will not go in without undue forcing should be used.

The fuel pump should be disassembled and inspected for wear. The maximum allowable clearances are as follows:

Internal-gear shaft in bearing.....	0.006 inch
Internal gear in housing.....	0.008 inch
Contex gear on pin	0.004 inch
Contex gear to cover.....	0.004 inch

Remove the valves and see that the seats are in good condition. Lap if necessary. Inspect the packing on the shaft and replace if not in good condition. Any gas leaking past this goes into the crankcase and dilutes the oil. The contex gear should not project above the

end of the internal gear. Adjustment to the desired end clearance of 0.002 to 0.004 inch can be made by varying the thickness of the cover gasket or, if necessary, by grinding either of the two gears.

If their condition warrants it, the cylinder valve seats should be cut, using the tools listed for that purpose, and the valves faced off in a grinder. They should then be ground and tested for tightness with gasoline.

Replacement of Valve Guides.—If the valve guides in a cylinder become worn, allowing excessive clearances, it is advisable to replace them with new parts. By so doing the valves are held straight on their seats and loss of compression, leaks, and burned valves are avoided.

The intake- and exhaust-valve guides on Models J-4A and J-4B engines and the intake-valve guides on Model J-5 engine are of bronze necessitating the use of counterbores in removing them. Set the cylinder up in a suitable machine and run the counterbore through the guide, the pilot centering the tool and preventing injury to the cylinder. This leaves a shell $\frac{1}{64}$ inch thick which can be removed with a cape chisel. Attempts to drive the guides out with a drift are very likely to end in their seizure in the bosses, necessitating replacement with oversized parts.

The J-5 exhaust-valve guide is of hardened tungsten steel and can be pulled out without danger of seizure. The guide boss should first be heated for several minutes with a blow torch applied through the valve port. A puller should be put on the guide removed.

Method of Replacing Guides, J-4A, J-4B, and J-5.—1. Inspect the hole from which the guide has been removed and measure its diameter with inside calipers and a micrometer. The hole should be from 0.001 to 0.002 inch smaller than the guide which is used for replacement. It will usually be found possible to use standard guides for replacement, but if the hole is found to be mutilated or less than 0.001 inch below the O. D. of the guide, an oversize replacement guide will be necessary.

2. If it is found necessary to use an oversize replacement guide, the cylinder guide hole should be reamed to a diameter from 0.001 to 0.002 inch less than the outside diameter of the guide. In other words, a drive fit of from 0.001 to 0.002 inch is desired. The reaming operation should be carefully done, using the reamer pilot bushing, as it is absolutely necessary to hold to these limits. A tighter fit may break the cylinder, and a looser fit may allow the guide to come loose in service.

3. Insert in the new guide the special drive provided and tighten the drift nut.

4. The valve-guide bosses should be heated with a blow torch before driving in the guides.

5. With a wooden or rawhide mallet, drive home the guide until the shoulder seats firmly on cylinder. Remove the drift.

6. Ream the inside diameter of the guide with the finish reamer, to give a clearance of 0.002 to 0.003 inch over the inlet-valve stem and from 0.003 to 0.005 inch over the exhaust-valve stem on J-4A and J-4B engines.

7. The J-5 intake valve guide should be reamed to a clearance over the valve stem of 0.004 to 0.006.

8. The J-5 exhaust-valve guide is ground to size at the factory. The reaming operation is unnecessary, as the guide will not contract when inserted in the cylinder.

Check the thickness of the metal above the J-4-series rocker-arm ball cups and replace if this is less than $\frac{5}{64}$ inch (0.078 inch). An easy way to make the measurement is to set a pair of outside calipers at $\frac{1}{2}$ inch (0.500 inch) and with one point located in the bottom of the cup to measure the distance from the outside of the rocker arm to the other point with a scale. The desired dimension can then be obtained by subtraction.

Inspect each push-rod ball end for roundness and for signs of contact with the rocker on the ball neck. If the rocker has been hitting, the ball end should be replaced.

ASSEMBLY

The successful operation of the engine is absolutely dependent on the attention given to every detail in inspection and assembly. It should be constantly borne in mind that the slightest neglect on the part of inspector or mechanic may result in the failure of the engine and the possible loss of one or more lives.

Cotter pins and lock wires which have been badly bent should never be used again.

Great care should be taken to prevent dirt, dust, cottor pins, lock wires, nuts, washers, and other small parts from falling into the inside of the engine. These might work into the gears or oil lines and cause immeasurable damage.

If the engine is to stand for any length of time before being used, all steel parts, both inside and outside, should be covered with oil to

prevent rust. Completely finish each step in the process of assembling as the work progresses. Do not leave a bolt loose or a nut not cottered, with the idea of coming back to it later on.

Never slack off on a nut in order to line up the notch in the nut with the cotter-pin hole in the bolt or stud. If it cannot be tightened sufficiently with reasonable effort replace it with another nut.

Before being assembled in the engine, all parts should be thoroughly cleansed and made free from grit. Wipe with a clean, dry rag which is free from lint. Do not use waste or tattered rags, pieces of which might be left unnoticed inside the engine and clog up pipes or strainers.

Remember that the engine will turn over a number of times before the oil pump will start to furnish the regular supply of oil; therefore, coat all bearing surfaces with a good supply of standard engine oil before assembling. All studs, nuts, and parts which are a drive fit should likewise be oiled. In the assembly procedure following, it will be assumed that this has been done where necessary.

In places where there is the possibility of oil leaking out between two machined surfaces, as under the cylinder hold-down flanges, it is recommended that the surfaces be coated with soft soap before assembling. This should be of good quality and free from lumps or foreign matter. Soap presents many advantages over the compounds most generally used for sealing and is highly recommended.

For convenience in assembling the engine, a list of the various parts and the location of their identification numbers is given below.

Cylinders.—The engine number and the cylinder number are stamped on the cylinder head over the intake port.

Valves.—The cylinder number is etched on the upper side of the valve head.

Rocker Boxes.—The cylinder number is stamped over the rocker-arm pin boss.

Crankcase.—The engine number is stamped on the side of cylinder 1 pad, and the cylinder number is stamped on the front side of each pad.

Crankshaft.—The engine number is stamped in the aluminum plug in the front end.

Master Rod.—The engine number is stamped on top of the front flange. The four clamping bolts are numbered, and corresponding numbers are stamped at the top ends of the four holes.

Pistons.—The cylinder number is stamped on the top of each piston toward the front of the engine, and the engine number is on the opposite side.

Link Rods.—The link rods bear the engine and cylinder numbers on the front side near the piston end.

Wristpins.—The cylinder number is stamped on the end plug in each wristpin.

Knuckle Pins.—The cylinder number is etched on the top of each knuckle pin.

1. Crankcase.—After cleaning the crankcase, bolt it securely to the assembly stand by at least four good bolts.

2. Crankshaft.—If the crankshaft main bearings have been removed, they should be replaced in their original positions. The manufacturers' names and numbers face the ends of the shaft. The retaining nut on the rear end of the shaft should be run up against the bearing and the slinger until it is in its original position, as shown by the center-punch mark on the shaft and the lock-wire hole in the nut. The lock wire should then be replaced. Any plugs which have been removed for cleaning the shaft should be replaced and locked in place with a center punch.

The roller bearings should then be filled with vaseline, and the crankshaft inserted in place in the crankcase.

3. Connecting Rods.—Tilt the stand so that the crankshaft is in a vertical position.

The two halves of the master-rod bearing should then be put back in their places in the two parts of the rod, and the babbitted surfaces coated with oil. The crankpin should also be oiled. Place the upper part of the master rod in position with the shank protruding from the No.1 or top-cylinder opening. Place the lower part of the rod in position, making sure that the knuckle-pin lock-plate screw holes are facing up. Replace the four clamping screws in their proper places according to the numbers on the screws and the rod and turn up with a socket wrench, until the numbers on the screw heads correspond with those on the master rod when set up tightly. It is best first to tighten up all the screws until they are quite snug and then to bring them all up to their proper positions, a few degrees at a time. This insures a uniform set of the two halves and avoids the application of unnecessary strains. The bottom, or rear, screws should be wired, using the two small holes provided in the rear flange of the rod. It is of the greatest importance that this be done and done well.

The link rods should then be put in. Coat the bushing in the rod and the knuckle pin with oil and slip the rod into place with the number

up. Thrust the knuckle pin into position as far as it will go by hand and then tap it down with a block of fiber or hard wood. The straight side of the pin top should be facing the lock-plate screw hole. If it does not seem to be in alignment after assembly, it can be turned by carefully using a brass drift on one side or the other. The rods should all be put in this fashion and the pins locked in place with the locking plates and screws. The two lower screws should then be wired together, and each of the upper screws should be wired to the nearer master-rod clamp screw.

4. Intermediate Section.—The intermediate section should then be put in position and tapped down over the front crankshaft roller bearing. A dowel in the face of the main crankcase permits the intermediate section to be put on in none but the correct position. The oil slinger, the small steel spacing ring, and the cam should next be slid on over the crankshaft in the order named. The internal gear on the cam faces the front of the engine. The cam-drive gear, well oiled, is then tapped into place, the cam bearing sliding inside the cam hub and locating itself on the key in the crankshaft.

5. Front Section.—If the cam and magneto drive shaft has been removed from the front section, it should then be replaced. The front section should be assembled in place, with the long crankcase stud extending through the oil drain pipe boss at the bottom (J-5). On J-4A and J-4B engines, the oil drain pipe is connected at the bottom of the intermediate section.

Put washers and castellated nuts on the crankcase studs and draw them up tight. Lock with one wire running all the way around the case. Slip the crankshaft spacer and the thrust-bearing rear oil slinger into place. On J-4A and J-4B engines, this slinger is almost flat, while on the J-5, it is spun over in an arc of almost 90 degrees. The front slinger is the same in all models. Fill the thrust bearing with vaseline and tap it into place.

Put on the thrust-bearing front oil slinger and the crankshaft nut. Tighten the nut until the crankshaft has been pulled up into position and the center-punch mark on the crankshaft comes opposite the locking-wire hole on the nut.

6. Pistons and Cylinders.—In replacing the pistons and cylinders, always put on piston 1 and cylinder 1 first.

Cylinders of Models J-4A and J-4B engines should be assembled complete with valves, springs, and rocker arms before putting them

on the engine. Model J-5 cylinders should have only the valves, springs, and washers, leaving the valve-operating gear until later.

If the wristpins are a tight fit, the pistons should be heated before they are put on the engine. This can be done with hot water or in a small oven of some sort.

Hold the piston in position and push the wristpin into place so that the plug ends are flush with the outside of the piston. Apply a liberal coating of oil to the piston and the inside of the cylinder sleeve. Compress the piston rings with ring clamp and slide the cylinder over the top rings. Shift the clamp to the bottom ring and slide the cylinder into its proper position in the crankcase. Secure with the eight hold-down nuts and locknuts.

It is perhaps unnecessary to observe that the cylinder cannot be put on with the spark plugs in their bushings. A very convenient and safe system is to have on hand a number of old spark-plug shells which have had bits of 60-mesh screen soldered onto the outer ends. The regular plugs can be put in the rear bushings, and these dummies in the front. This prevents dirt and chips from entering the combustion chambers while the engine is being assembled and still allows the mechanics to rotate the crankshaft freely.

Replace the intake pipes.

7. Valve-operating Mechanism.—On the Models J-4A and J-4B assembling, the valve gear consists in inserting the push rods in position. The inside camfollower (nearer the cylinder) operates the intake valve, and the outside follower (toward the propeller) operates the exhaust valve.

The J-5 assembly is more complicated. The rocker-box and push-rod housing assembly is put back in position, and the nuts and washers are replaced. Do not forget the spacing washers which go on the two front studs before the rocker boxes are put on. On the early engines it is very easy to confuse these washers (No. 19,414) with the washers under the nuts holding down the rocker box (No. 19,413). They can be identified as follows: No. 19,414 (under the box) is 0.031 inch ($\frac{1}{32}$ inch) thick and is ground on both sides, while No 19,413 (inside the box) is 0.047 inch ($\frac{3}{64}$ inch) thick and is not ground. No. 19,413 is also used at top and bottom of the rocker-box springs. On the later engines, spacer No. 20,313 is used in place of the two washers No. 19,414. The packing nut at the top of the housing should be adjusted to give

0.031 inch clearance between the rear end of the rocker box and the cylinder pad. The push-rod ball ends should then be dipped in oil (preferably 600W) and the rods inserted in the housing. Then the rocker arms are assembled in place. Be sure that the hardened steel push-rod ball cup is in place. If the cups are coated with heavy oil on the outside before inserting in the rocker arm, they will stick in place, and much annoyance will be avoided. The castellated nut which locates the rocker-arm pin in the housing should be turned up until it is snug and cotter-pinned in place. Be sure that this nut is tight as it clamps the thrust washers against the steel bushing on the rocker and insures the proper bearing of the rocker arm.

8. Ignition System.—Replace the ignition system in the reverse order of disassembly.

9. Timing.—The engine is then ready for timing. The rear face of the propeller hub is marked with the proper angles and can be used in this operation. When it is not desired to remove the hub from the propeller, or when a metal propeller is being used, timing disc WA-138 and hub WA-265 are necessary. Put on whichever hub is to be used.

Insert the top center indicator WA-43 into the front spark-plug bushing of the No.1 or top cylinder (rear bushing on J-4A and some J-4B engines):

Set the tappet clearance on cylinder 1 valves at the proper value for timing. For all models this is 0.060 inch.

With a piece of sheet metal and a pair of shears make a pointer and attach loosely to the engine on the two top nose-plate studs.

Remove the cotter pin and loosen the hex nut on the end of the cam and magneto drive shaft. This is located in the nose of the engine directly above the crankshaft. Remove the breather (J-4A and J-4B) or the plug (J-5) located on top of the crankcase front section directly between the magnetos.

Set piston 1 on top dead center, as shown on the indicator.

Adjust the sheet-metal pointer to cylinder 1 top center mark on the hub. If the timing disc is being used, secure the pointer tightly to the engine and make a mark opposite on the disc.

Rotate the shaft until the intake valve on the No.1 or top cylinder begins to open. This point is best determined by rocking the tappet roller with the thumb and forefinger and noting the point at which it comes into contact with the valve end.

Remove the timing disc or hub, being careful not to disturb the setting of the cam. Insert a screwdriver through the breather hole and separate the serrated discs, or timing dogs. On Model J-5, the serrated surfaces are between the hub faces of the magneto and the cam-drive gears, while on the J-4 series engines, they are located in front of the two gears.

Replace the hub and turn the crankshaft in the direction of rotation until the pointer indicates 8 degrees before the top center mark previously mentioned.

Engage the dogs and secure them by turning up on the cam-drive shaft nut.

Check the setting of both intake and exhaust valves. As cams are subject to slight variation, it is probable that when the intake opens at 8 degrees before top center, the exhaust will close at from 8 to 10 degrees after top center. Whatever this difference is, it should be split and added equally to both sides, so that the valves operate at equal angles on either side of top center.

When the timing is correct, tighten and cotter the cam driveshaft nut. Replace the breather cap (J-4A and J-4B) or plug (J-5). Remove the top center indicator.

To adjust the magneto timing, first set cylinder 1 on the compression stroke at 30 degrees before top center, as indicated on the hub or timing disc. If the valve timing has just been adjusted, this is done by turning the crankshaft through approximately one complete revolution.

Then set the magnetos on cylinder 1 with the breaker points just separating. To do this, proceed as follows: Push the coupling toward the magneto until it disengages from the engine drive gear and rotate it until the firing point of cylinder 1 is reached. This occurs when the marks on the distributor drive gear coincide with those on the casing. The right side of the magneto has double, while the left side has single marks. The firing point can also be determined by watching through the small observation window until the numeral 1 appears. The exact location of the point is obtained by putting a slight tension on a piece of thin paper held between the breaker points. When the points separate and the paper is released, hold this setting securely, disengage the coupling completely, and rotate until the two pairs of gears engage.

Repeat with the other magneto.

As soon as both are timed, a check should be made to see that the two are synchronized. Insert pieces of paper between the breaker points and rotate the crankshaft until both are released. The difference between the two should not exceed $\frac{1}{2}$ degree. Make sure that no paper is left between the breaker points.

Cotter the couplings and replace the distributor blocks and breaker-mechanism covers.

10. Rear Section.—The rear section should then be replaced. Coat the rear end of the crankshaft and the bronze bearing inside the rear section with oil and slide the rear section into place. Replace the retaining nuts and washers. The bottom stud is behind the oil strainer, and, on account of its position, is likely to be forgotten. Oil the shaft on the accessories drive gear and tap it into place, rotating the accessories gears until they are in mesh. Tap the starter dog into place in the end of the drive gear and lock both in the shaft with the long steel screw. Replace the starter.

11. Tappet Clearance.—On Models J-4A and J-4B, the tappet clearance is set at 0.010 inch for both intake and exhaust. The adjustment is made on the upper end of the push rods where the ball-end shank screws into the rod proper. Keep the rod from rotating by means of a wrench on the hex provided for that purpose, loosen the locknut, and then screw the ball end in or out until the 0.010 inch feeler becomes a snug fit between the roller and the valve plug. Bring the locknut up tight against the rod and then check the clearance to make sure that the ball end has not rotated while being locked. The adjustment on Model J-5 is quite different, the clearance for both tappets being 0.040. Loosen the clamping screw on the push-rod end of the rocker arm and with a large screwdriver turn down on the adjusting screw until the rocker roller touches the valve plug. Then back off on the adjusting screw until the arrow on top has passed eight divisions of the scale on the rocker arm (each division is equivalent to 0.005-inch clearance on the valve stem). Lock in place by tightening the clamping screw.

12. Miscellaneous.—Replace the carbureter, the oil drain pipe, and the rocker-box covers.

13. Propeller Hub.—The procedure in putting on the propeller hub is described on page 175.

SERVICE SUGGESTIONS

The lubricating oils listed below have demonstrated by extensive service that they are satisfactory for use in Wright engines.

Summer Grade:

Gargoyle Mobiloil B (97-101)
 Hyvis Extra heavy (110)
 Kendall G (106)
 Marland super Liberty (100)
 Marvelube Extra heavy (103)
 Pennzoil Aviation special (100)
 Stanolind Superla (90-95)
 Valvoline special heavy (95)
 Veedol Extra heavy (106)
 Wolfshead No. 8 (98)
 Zerolene Aero—2 (95)

Winter Grade:

Gargoyle Mobiloil BB (75)
 Hyvis special heavy (85)
 Kendall F (87)
 Marvelube Special heavy (75)
 Pennzoil Extra heavy (85)
 Stanolind Superla (80-85)
 Veedol special heavy (74)
 Warren A B C
 Zerolene Aero—1 (80)

Numerous engine operators seem inclined to use a heavier summer oil than the grade recommended by the Wright Aeronautical Corporation. This practice has met with success during warm weather and is permissible, if desired. The following brands of oil have been used with satisfaction.

Kendall J (125)
 Magnoline (125-130)
 Pennzoil Double Extra heavy (115)
 Stanolind Aero (125)
 Valvoline Extra heavy special (122)
 Veedol Liberty Aero No. 4 (116)

When a heated hangar is always available, or some method of preheating the oil is employed, it is possible to use an oil of summer grade during the winter time if desired *but this practice is not recommended*. Better satisfaction will be obtained with one of the winter grade oils listed above. *The six oils just listed should not be used during cold weather under any condition.*

In all the tables given above the oils are listed in alphabetical order. The figures in parentheses are the viscosities at 210° F.

The aluminum plugs in the Whirlwind and Cyclone engine knuckle pins are a press fit in the pin and should not be removed unless absolutely necessary. *It is necessary to use a new part in replacing the plug in order to obtain the required tight fit.*

A large number of airplane manufacturers do not install a shut-off cock in the primer line near the Lunkenheimer primer furnished with the engine. It is then possible for raw gasoline to be sucked into the engine causing roughness of operation. It is also possible for the leakage to be severe enough to cause dripping at the carbureter. The shut-off cock should be installed in the line near the primer and should be provided with a right-angled handle which in the off position will extend across the primer handle.

In addition to this difficulty, due to the absence of a shut-off cock on the priming line several instances have been experienced wherein gasoline has leaked past the primer pump and into one of the two lowest cylinders, filling it with raw gasoline to such an extent that when the piston approached top center it came in contact with this solid mass of gasoline with such force that the connecting rod was bent, necessitating its immediate replacement. Even though a shut-off cock is installed there is a possibility that through negligence it might be left in the open position with the result noted above.

To definitely eliminate any such possibility it is urgently recommended that the priming system be changed as noted below:

Remove the priming pipes between Nos. 1 and 2 and 1 and 9 intake passages in the rear of the crankcase section. Remove the priming tee and elbow from Nos. 2 and 9 intake passages. The holes in Nos. 2 and 9 intake passages should then be plugged up with a $\frac{1}{8}$ -inch brass-pipe plug. White lead or shellac should be placed on the threads to insure an air-tight plug. The intake passages to cylinders 3 and 8 should then be drilled and tapped ($\frac{1}{8}$ -inch pipe) in the center line of the passages approximately $1\frac{3}{4}$ inches from the inside edge of the mounting flange and square to the surface of the metal. Heavy grease should be placed on the drills and taps to eliminate the possibility of chips falling into the intake passages. The priming tee and elbow should then be placed in the holes using white lead or shellac. Longer $\frac{1}{8}$ -inch seamless tubing should be used to connect Nos. 1 and 3 and 1 and 8 intake passages.

With the priming system installed as above, the possibility of any of the cylinders filling up with gasoline is eliminated. If the priming cock is accidentally left open, the gasoline will run into 3 or 8 (depending upon which side the engine is primed) intake passage and then down through the intake passages and out the carbureter.

Oil Consumption.—Examination of master-rod bearings, which have been removed from engines having excessive oil consumption, has disclosed that in many cases considerable leakage has occurred at the parting line on the bearing. In other cases, the leakage has been caused by the former practice of burnishing the bearings by hand, thereby breaking down the sharp corners of the two halves of the bearing halves, thus forming four small

triangular passages through which a considerable quantity of oil could escape. In other cases, oil leakage has been discovered between the backs of the bearing halves and their seats in the master rods.

The following precautions should be taken when inspecting and assembling these parts on engines which have been in service:

Check the fit of the bearing halves in the respective halves of the master rod. This check is made by "bluing" the backs of both bearing halves and the parting surfaces of one half. The bearing is then assembled in the master rod without the crankshaft. The "blue" should be slightly heavier than that commonly used in fitting babbitt bearings. All surfaces should be scrupulously cleaned by polishing with crocus cloth and gasoline before the blue is applied. Tighten all four bolts until the numbers on them are exactly in line with the corresponding numbers on the master rod. The fit of the bearing should be checked along the oil chamfer by attempting to insert a 0.0015-inch feeler gage. This is the point previously mentioned at which considerable oil has been found to escape. Disassemble the master rod and examine the distribution of the blue. It is not practicable to establish any specific bearing percentages for these fits on service engines; however, it is essential that you satisfy yourself that no leakage exists at the points mentioned.

The diametrical clearance of the master-rod bearing should then be checked on the crankshaft journal. This clearance should not be less than 0.0025 inch nor more than 0.003 inch. Bearing clearances of less than 0.0025 inch have been found, in some cases, to lower the quantity of oil released in the crankcase to the extent that the seizure of one of the upper pistons is liable to occur.

Crankshaft Plug.—On the early model Whirlwind the crankshaft accessory drive gear bolt nut had a small boss to receive the accessory drive gear bolt. The design of this boss was such that when assembling the engine the bolt would sometimes jam between the boss and the shaft. With the new nut the boss has a "flared" opening which receives the bolt, thus making it impossible to jam the bolt between the boss and the shaft. It is recommended that the old nut be replaced with the new type whenever an engine is torn down.

Holes in Piston-pin Plugs.—All piston-pin plugs on J-5 engines should have a No. 52 hole drilled in the plug approximately $\frac{1}{16}$ inch from the flange. These holes are the means by which the air imprisoned in the piston pins can be relieved. Before the holes were drilled, in the case of tight-fitting plugs, the pressure of the imprisoned air would cause the plugs to bear on the cylinder walls, causing undue wear.

Operators should see that these holes are drilled at the first top overhaul.

CHAPTER 5

THE BLISS JUPITER ENGINE

The Jupiter engine, originated by the Bristol Company of England, and now being built by the E. W. Bliss Company in this country, is a nine-cylinder radial, air cooled, and built with varying compression

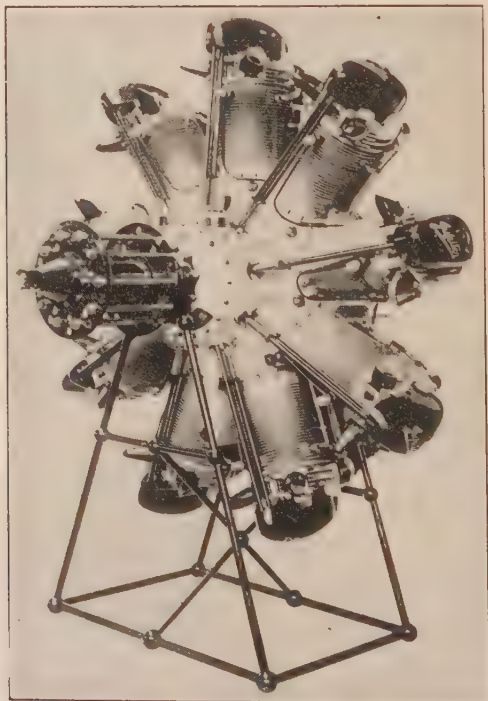


FIG. 1.—Propellor end of Bliss Jupiter engine.

ratios according to the service for which it is intended. These compression ratios vary from 5 to 6.3 to 1. The engine is shown in Fig. 1.

The crankcase is a duralumin drop forging subjected to approximately 250 blows from a 7-ton hammer. It is machined all over and heat

treated. The crankshaft is in two parts, so as to permit the use of a solid-end master connecting rod as in Fig. 2, which shows the two parts of the counterbalanced crankshaft, the master rod, the floating bronze bushing, and the clamping bolt.

The cam sleeve, with four inlet cam lobes at the front, is driven from the crankshaft by a patented eccentric epicyclic gear, shown in Fig. 3. The action of the gears is shown in the partial assembly. This arrangement drives the cam gear one-eighth the engine speed. The large number of teeth in mesh gives a very smooth drive.

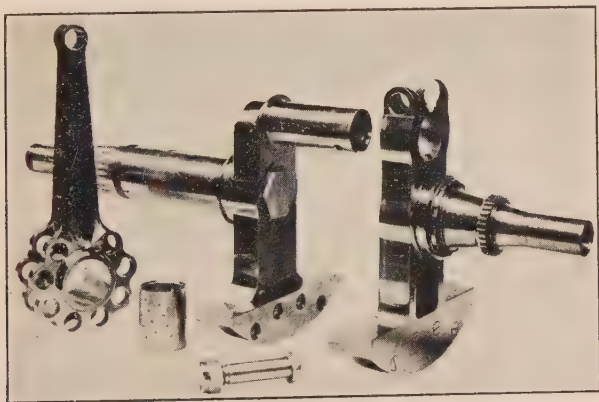


FIG. 2.—Crankshaft, master rod and bushing.

Cylinders (Fig. 4) are machined from steel forgings weighing about 88 pounds in the rough and 18 pounds finished. The head is integral with the cylinder, and the four valves seat directly in the head. This makes it unnecessary to shrink the aluminum heads in place. The joint between the cylinder and the head is carefully machined to insure maximum heat conductivity. By the use of Invar, which has a negligible expansion, around the exhaust ports, these joints have a life of upwards of 500 hours without attention. The fins are machined from the solid and are eccentric, being deeper at the back of the cylinder, the compensate for the reduced air flow in that region.

Pistons are of the slipper type and seem unusually short on this account, as in Fig 5. They have three rings: the lower ring being an

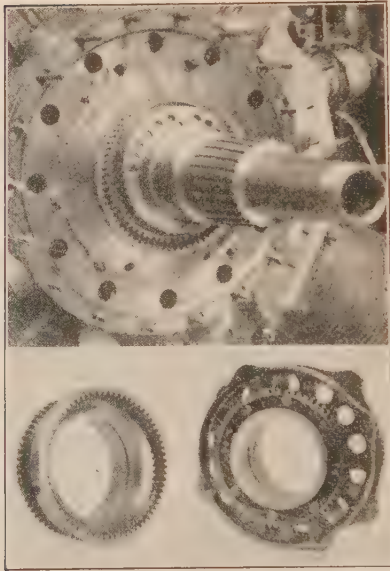


FIG. 3.—Differential cam gear.

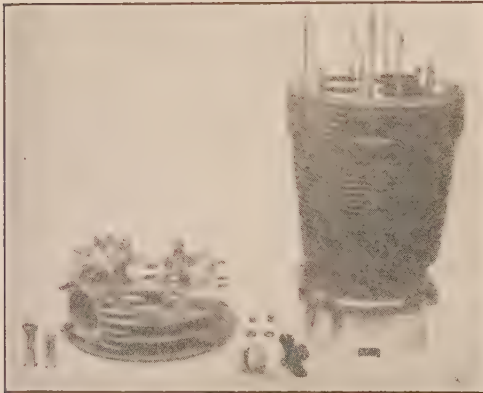


FIG. 4.—Jupiter cylinder and head.

oil scraper that returns surplus oil through holes through the skirt of the piston. The pin floats in both piston and rod.

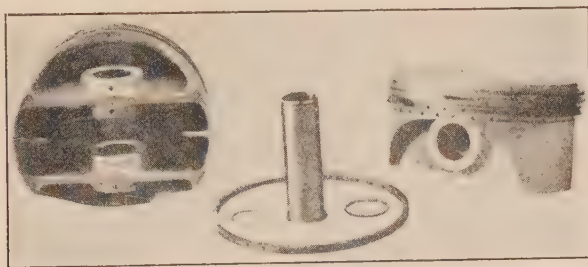


FIG. 5.—Piston, pin and ring.

The valve guides are floating, and have a spherical seat so as to insure accurate seating under any running condition. The details can be

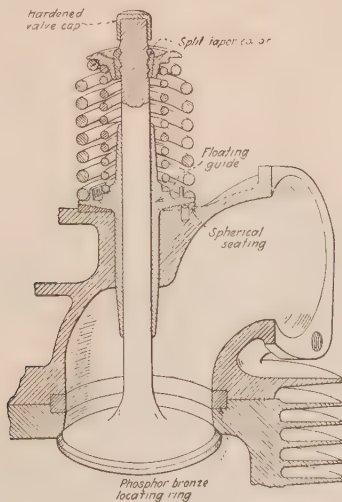


FIG. 6.—Detail of valve assembly.

seen in Fig. 6, which shows the bronze locating ring between cylinder and head, the double valve spring, and the hardened cap on the valve stem.

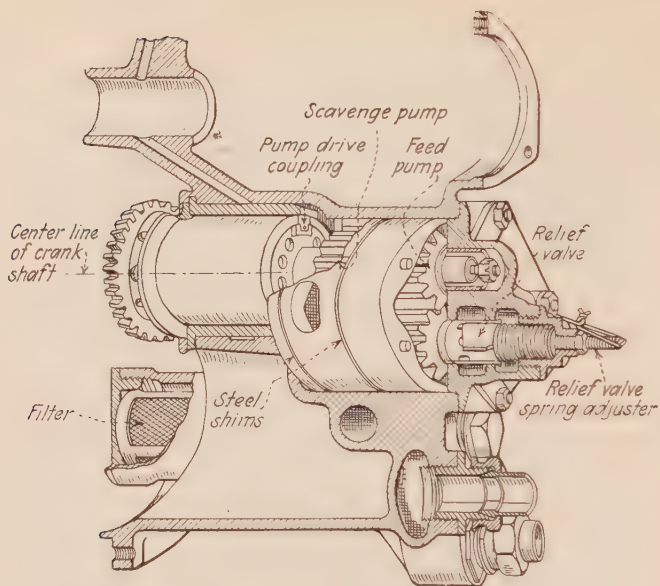


FIG. 7.—Detail of oil pump assembly.

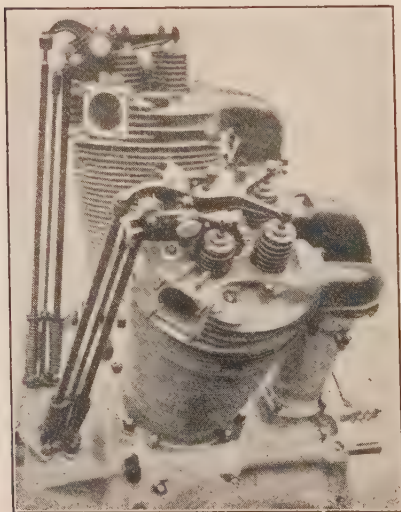


FIG. 8.—Rocker compensating gear.

The oil-pump assembly (Fig. 7) shows both the feed and scavenging pumps, the relief valve, and other parts. The scavenging pump has about 30 per cent greater capacity than the feed to insure prompt removal of oil after going through the engine. Large, independent filters in both the feed and scavenging circuits can be removed and

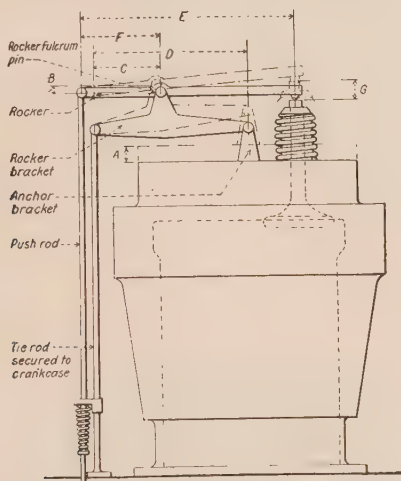


FIG. 9.—Details of clearance compensator.

A, Cylinder expansion

B, Rise in rocker fulcrum pin— C/D times A = approx. $0.44A$

G , Rise in valve end of rocker = E/F times B

Inlet rocker $G = \frac{2.58}{1} \times 0.44A = 1.13A$

Exh. rocker $G = \frac{2}{1} \times 0.44A = 0.88A$

Therefore, as engine warms up, the inlet clearance increases, and the exhaust decreases

Actual clearances cold—inlet 0.004, exhaust 0.016

Average clearances hot—inlet 0.010, exhaust 0.010

cleaned without breaking the oil-pipe lines. A spring-loaded relief valve can be easily set to the desired pressure and locked so as to require no attention between engine overhauls. The whole unit is housed in a chamber in the rear crankcase cover and is easily detached.

To avoid variations in valve clearance, due to heating of cylinders, a compensating device is used, as seen in Figs. 8 and 9. The first shows the cylinder head and gear, and the next the way in which the

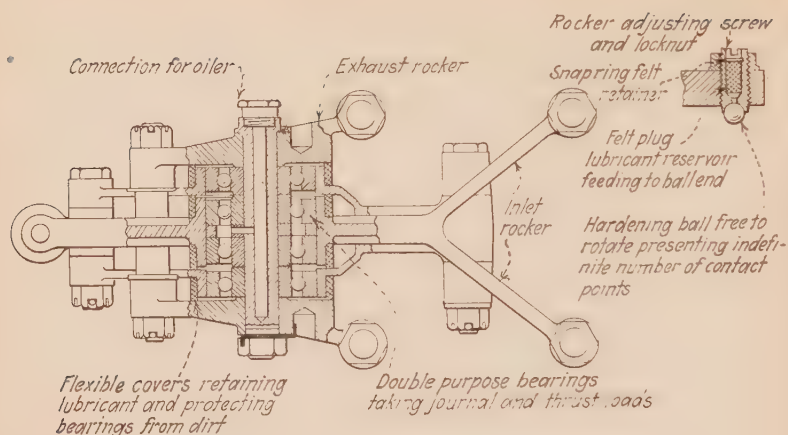


FIG. 10.—Jupiter ball bearing rocker gear.

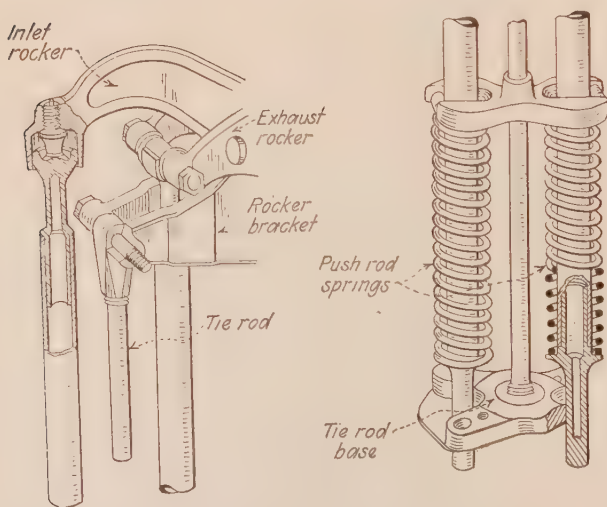


FIG. 11.—Push rod assembly.

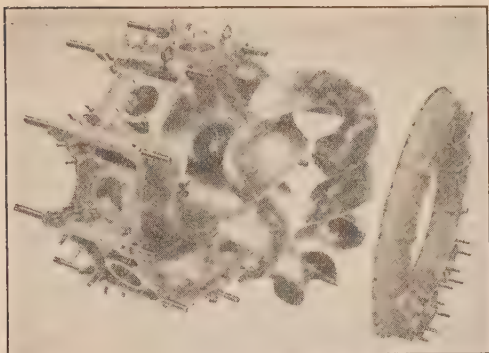


FIG. 12.—The induction spiral.



FIG. 13.—Jupiter gear-driven supercharger.

compensation is secured. The compensation is secured by the movement of one end of the rocker bracket with the cylinder head, while the other end is controlled by the rod running to the crankcase. Details of the ballbearing rocker gear can be seen in Fig. 10. Details of the push-rod assembly is seen in Fig. 11. The springs fitted to the inner ends of the push rods serve as auxiliary valve springs and compensate for the inertia forces on the push rods, relieving the valve springs of this extra load.

A triplex carbureter is used to insure even distribution of fuel to all cylinders. Each carbureter feeds one start of an induction spiral so designed that each start feeds three equally spaced cylinders. The induction spiral is housed in an annular induction chamber in the rear of the crankcase, as seen in Fig. 12.

Superchargers (Fig. 13), starters, and fuel pumps are provided when desired. The firing order is 1-3-5-7-9-2-4-6-8.

The main dimensions and characteristics are summarized as follows:

BLISS—JUPITER

Type.....	Nine-cylinder air-cooled radial			
Bore.....	5.75 inches			
Stroke.....	7.5 inches			
Total stroke volume.....	1,753 cubic inches			
Normal engine speed.....	1,700 r.p.m.			
Maximum engine speed.....	1,870 r.p.m.			
Propeller.....	Direct-drive left-hand tractor			
Carbureter.....	1 "Bristol" Triplex, oil heated			
Ignition.....	Dual, 2 high tension magnetos			
Ignition control.....	Fixed			
Oil system.....	Pressure 40 pounds per square inch			
Tachometer drive.....	¼ engine r.p.m.			
Fuel recommended.....	Standard service 8 ⁰ / ₂₀ benzole mixture			
Oil recommended.....	Castrol R, or pure-treated pharmaceu- tical castor			
Standard weight, bare.....	720 pounds			
	Jupiter VI.A.	VI.A.M.	VI.A.I.	
Compression ratio.....	6.3	5.3	5	
Rated brake horsepower at normal r.p.m.....	415 at 5,000 feet	440	420	
Rated brake horsepower at maxi- mum r.p.m.....	455 at 5,000 feet	485	460	

BLISS—TITAN

Type.....	Five-cylinder air-cooled radial
Bore.....	5.75 inches
Stroke.....	6.5 inches ²
Total swept volume.....	842 cubic inches
Compression ratio.....	5: 1
Rated power and r.p.m.....	200 brake horsepower at 1,700 r.p.m.
Power at maximum r.p.m.....	220 brake horsepower at 1,870 r.p.m.
Propeller.....	Direct drive L.H. tractor
Carbureter.....	Bristol Duplex, oil heated
Ignition.....	Dual 2 high tension magnetos
Lubrication system.....	Pressure
Tachometer drive.....	$\frac{1}{4}$ engine r.p.m.
Dry weight.....	500 pounds
Rated consumptions:	
Fuel.....	13 gallons per hour
Oil.....	2 pints per hour

CHAPTER 6

THE LEBLOND "SIXTY" ENGINE

The LeBlond Sixty aircraft engine is a five-cylinder radial and has many interesting features in its design. Unlike other engines of this type, the cylinder heads are cast integral with the barrel instead of being of aluminum and separate. There are also several unusual features in the connecting rod design. The front of the engine is shown in Fig. 1, and the back in Fig. 2, while the sectional views in Fig. 3 show construction details in two planes.

This engine has been designed both to secure simplicity and to permit the various units to be made up in individual assemblies. Each unit can, therefore, be properly assembled and inspected before it becomes a part of a complete engine. Nearly 90 per cent of the parts of the "sixty" are interchangeable with other LeBlond models.

The small overall diameter reduces head resistance and increases visibility. And in this compact arrangement due regard has been given to accessibility.

The assembly of a LeBlond Sixty engine starts with the crankcase assembly mounted upon the engine support. The crankshaft and

connecting-rod assembly is first inserted through the large opening at the front of the crankcase. This is most conveniently done when the crank axis is vertical. The link connecting rods can be placed opposite the respective openings for their cylinders, and then the crankcase cover assembly, which contains the ball thrust bearing, may be attached and the crankshaft located endwise by the thrust-

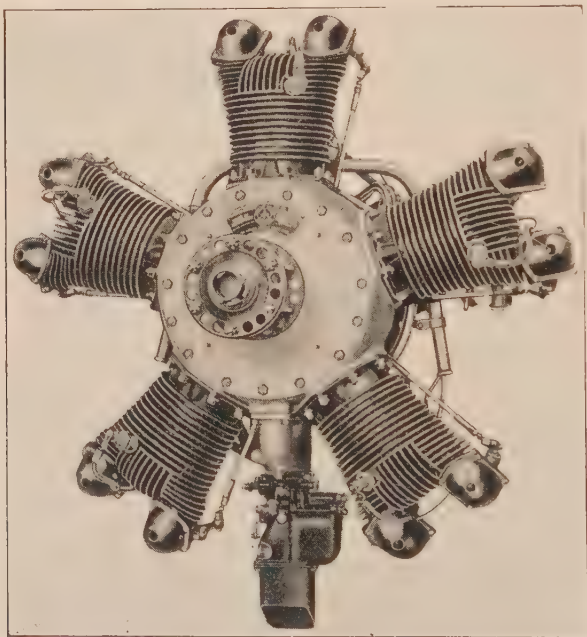


FIG. 1.—Front of LeBlond "60" engine.

bearing nut. Pistons and piston pins are attached to each connecting rod and everything is then ready for the individual cylinder assemblies. The gearcase is assembled as a unit from the rear, and after adjusting the push rods and timing the valves and magnetos, the gearcase cover is put in place, thus leaving only the carbureter, wiring manifold, and controls to be assembled before the engine is complete. This in brief covers the procedure of assembly and illustrates the extreme

simplicity of the design. Individual units such as the oil pump can be removed independently, and once an engine is assembled, the removal of the gearcase assembly, the crankshaft assembly, or both, does not require retiming the valves while putting the engine back together.

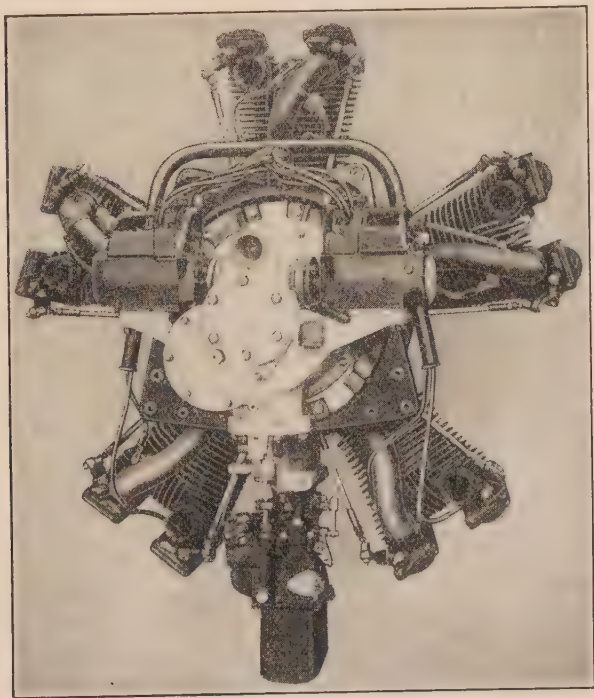


FIG. 2.—Rear view of same engine.

Crankshaft.—The single-throw crankshaft shown in Fig. 4 is drop-forged in one piece from nickel chromium steel. It is finish ground all over and counterbalanced by bronze weights which shoulder against two lugs on opposite sides of each crankcheek. These weights are located by screws which are permanently locked.

The crankshaft is supported upon two ball bearings, the one for the front being assembled later as it is locked endwise in the crankcase cover to carry the propeller thrust. The inner race of each bearing is

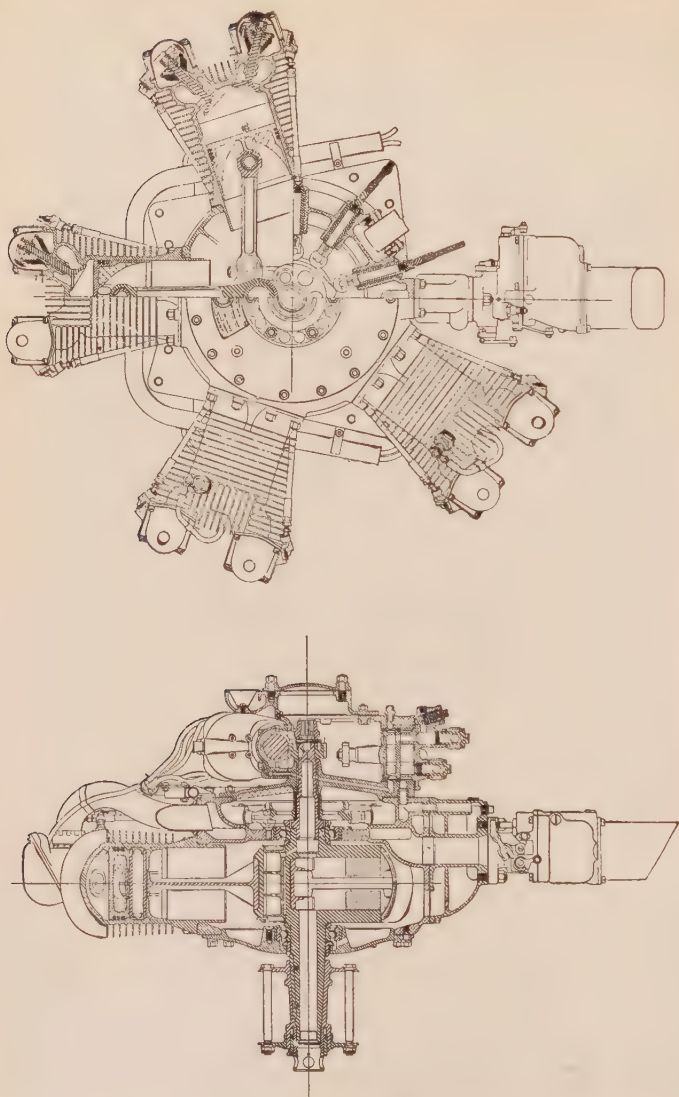


FIG. 3.—Construction details of LeBlond "60" in two planes.

locked on the shaft by a nut, and shoulders against a ring spacer which provides sufficient room for ample fillets between the crankshaft journal and cheek. The bearings are lubricated by splash.

For mounting the propeller hub, the crankshaft is provided with a tapered end in which there is a key slot and two tapped holes for the screws which retain the key. The shaft is hollow its entire length, the hole in the rear journal being made larger, and it is closed at the inner end by a Welch plug. The cam-drive shaft, which forms a part of the gearcase assembly, pilots into the end of the rear journal and is driven by the lugs which fit into the slot at the end of the crankshaft. These lugs are off center so it is impossible to assemble either crankshaft or gearcase, except in the correct position, once the valve timing is adjusted. Oil enters the crankshaft under pressure through the hollow cam-drive shaft. It then flows to the hollow crankpin by means of a hole drilled through the rear crankcheek.

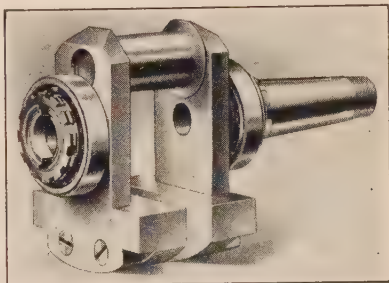


FIG. 4.—Single piece crankshaft.

The crankpin is provided with three holes for feeding oil to the connecting-rod bearing. The two smaller holes near the ends of the crankpin are so located as to match each revolution, with holes in the rod bearing that lead to the link rod wristpins. All the oil being fed to the bearings must first pass through a specially cast aluminum oil plug which is regarded as one of the interesting features of the design. This plug is so arranged that any heavy particles of dirt in the oil, which are naturally thrown to the outside by centrifugal force, become permanently trapped and are thereby prevented from passing through the bearing. Undoubtedly, this is an important factor in the unusual long life of the connecting-rod bearing. The oil plug is held in position by a cotter pin and it can be quickly removed at any time for cleaning.

Piston.—The piston is an aluminum alloy cast in permanent molds and heat treated. It has a full skirt and three rings above the piston pin, the lower ring functioning as an oil scraper. The piston pin is hollow, the outer surface being case hardened and lapped to exact dimensions.

In each end is pressed a duralumin plug to prevent the piston pin from scoring the cylinder walls.

Connecting Rods.—Articulated type connecting rods of simple design are employed, as in Fig. 5. The rods are made from nickel chromium steel drop forgings. The master connecting rod and cap have a full bearing upon the crankpin. The babbitt is applied directly to the steel and the two are bored to size. The cap is closely fitted to the master rod with a stepped joint and they are held together

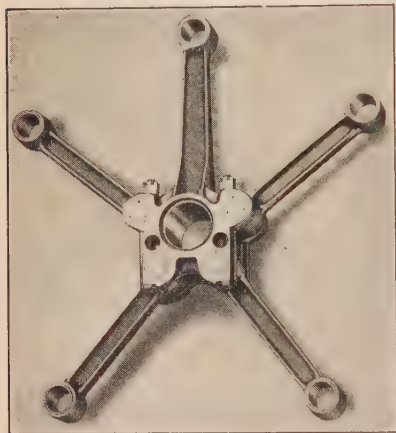


FIG. 5.—Connecting rod assembly.

and doweled by four nickel steel bolts. These bolts also securely lock the wristpins in place, thus eliminating numerous small parts that are so frequently used. The bolts have thin square heads which rest against shoulders to prevent turning and they are made tight by long hexagon nuts locked by cotters.

The link rods are interchangeable, and would be reversible if it were not for the necessity of placing the end which has the oil hole to the outside to permit splash lubrication of the bearing.

The bronze bushings which are

pressed into each end of the link rod and into the upper end of the master rod are alike.

The wristpins are hollow, and the ends are closed by Welch plugs that are permanently secured by peening. The half-round slots in the wristpins fit fairly close around the bolts, the undercut steps in the bolt being used in conjunction with drilled holes which line up with holes in the master rod and cap to supply oil under pressure to the interior of the hollow wristpins. Midway on the wristpin is a hole which leads oil to the link-rod bushing. All wristpins are interchangeable. The outer surface is case hardened, and exact dimensions together with a near-perfect finish are obtained by lapping.

Crankcase.—The crankcase is a heat-treated aluminum casting of high tensile strength. It has a large opening in front through which

the crankshaft and connecting rods may be inserted as an assembly. This opening also serves as a pilot for the crankcase cover, which is held in place by fifteen studs. A similar opening with ten studs at the rear permits attaching the gearcase assembly, and the hollow dowel through which the oil passes to the scavenging pump serves as a locator.

The integral inlet manifold is a separately cored passage in the form of a ring with openings to receive the inlet pipes and one which connects with the carbureter through the crankcase oil sump. Hence, there are few joints which might possibly develop leaks, and the oil is cooled by the incoming gases.

The wall central with this inlet manifold ring provides a support for the rear crankshaft bearing. The ball bearing is supported directly on a steel sleeve which is pressed into the crankcase and held in place by three counter-sunk headscrews permanently locked from turning.

Cast-iron bushings with holes ground to close limits are pressed into the crankcase to serve as guides for the camfollowers.

These camfollowers are in the same transverse plane, this being made possible by the use of the single cam ring.

The camfollowers are made from an alloy steel heat treated to give both hardness and toughness. The followers are drilled for lightness and receive at the outer ends a push-rod ball socket which is pressed into place. A special lock screw serves to keep the follower from turning about its axis and prevents any possibility of it dropping out when the push rods are not in place. At the inner end of the camfollower is a slot to guide the hardened roller and a half-round bearing for its two small journals. The safety wire is merely to insure that the roller will not drop out of place when it is not in contact with the cam as in assembly.

On the lower side of the crankcase, the finished pad with its studs provides a means of attaching the oil sump. Excess oil drains into

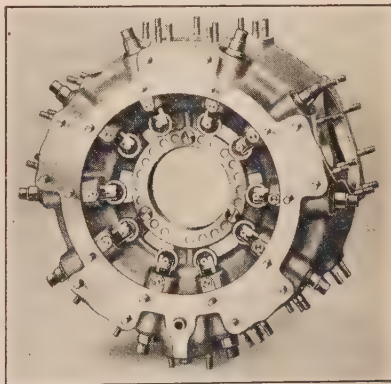


FIG. 6.—Crankcase assembly.

this sump from the crankcase both front and rear, and from there the oil is drawn through the hollow dowel, locating the oil sump, as it is being returned to the scavenging pump.

The crankcase and the parts which go to make up the assembly are shown in Fig. 6. All studs are made from alloy steel, and the threads are held to close limits to insure good fits.

Crankcase Cover Assembly.—The opening at the front of the crankcase is closed by a forged duralumin cover which is heat treated to obtain high tensile strength. This cover pilots into the crankcase and is held in place by fifteen studs.

The front crankshaft ball bearing is supported by the cover in a steel sleeve. This bearing is held endwise on the outer ball race to locate the crankshaft and to carry the thrust load of the propeller. Between the bearing and the crankshaft nut is an oil thrower which together with threads in the front of the crankcase cover prevents oil seepage to the outside. The nut on the crankshaft which screws up against the inner

race of the ball bearing is locked from turning by the propeller hub key since it extends into one of the turning slots on the nut.

On the front of the crankcase cover is a name plate and four studs which are to be used for attaching a support for the forward end of the cowling.

Cylinders.—The cylinders are cast in single units, with cooling fins integral, from a high grade of nickel iron as in Fig. 7. Each cylinder is held to the crankcase by eight studs which pass through the holddown flange. The inner end of the cylinder

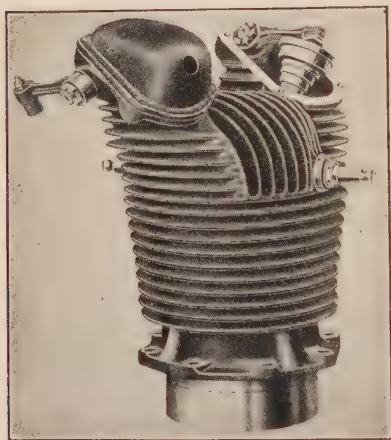


FIG. 7.—A complete cylinder.

barrel extends into the crankcase a distance sufficient to prevent over-oiling of the lower cylinders.

The combustion chamber is spherical in shape and provides seats for the interchangeable inlet and exhaust valves which are inclined at an angle of 30 degrees to the cylinder axis.

The valves are silchrome steel with 45-degree seats. Removable valve guides are pressed into the cylinder. The interchangeable valve springs are of the volute ribbon type holding about 60 pounds at the open valve position. Each valve is held by a split-retainer seating with a taper in the valve-spring collar, and a wire safety clip circles the valve stem below the collar to prevent the valve from dropping into the cylinder.

Two spark-plugs are provided. The inlet and exhaust valve ports face the rear, thus making it easy to attach an exhaust collector ring.

Threaded sleeves are screwed into each port and protrude sufficiently to receive an annular packing nut. The inlet pipe need not be disturbed while removing a cylinder. The valve rockers are pressed on to the squared ends of the rocker shafts which are supported in bronze bushings pressed into the cylinder. Lubrication of these bushings as well as the enclosed valve parts is accomplished through a fitting from the outside.

Propeller Hub.—The propeller hub (Fig. 8) is driven through a key on the tapered end of the crankshaft. A special nut with holes for a turning bar draws the hub up tightly on the taper. At the outer end of the hub is a puller nut against which the back face of the flange on the propeller hub nut bears when removing the hub from the crankshaft. These two nuts are provided with means for locking against turning when the hub is once in place. The propeller hub flange pilots on the front of the hub and the propeller pilots on both hub and flange and is held between the two by six special bolts and nuts.

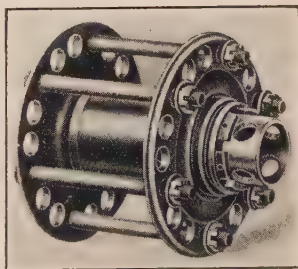


FIG. 8.—The propeller hub.

Gearcase.—The gearcase is assembled as a unit before it is incorporated into the final assembly of the engine (Fig. 9). The case itself is an aluminum casting, having a round flange and pilot where it attaches to the crankcase. In the central wall are two bosses, each receiving bronze shoulder bushings pressed in from the ends. On top is a pad for supporting the magneto drive shaft housing, and in line with it at each side is a bracket for supporting a magneto. Below is a flange for attaching the oil pump, the cylindrical opening the case in serving as the outer housing for the oil pump when the latter is in place. Sufficient

space is provided for assembly and adjustments by the opening at the rear.

The central boss supports the cam-drive shaft. Oil enters the interior of this shaft through a hole which is in line with the space between the ends of the bushings, and it passes directly through into the end of the crankshaft. It has already been explained that the end of the cam-drive shaft pilots into the end of the crankshaft and the two off-set lugs engage with the slot as a means of drive. The three-lobed cam is provided with a bronze bushing since it floats on the cam-drive shaft.

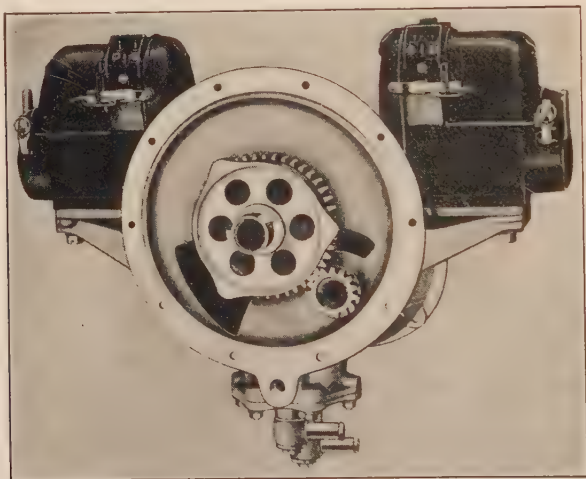


FIG. 9 — Gearcase assembly with magnetos.

Oil is fed directly to the bushing through holes in the wall of the cam drive shaft. The cam ring operates all valves and when the gearcase is in place these cams are in line with the camfollower rollers. At the rear end of the cam-drive shaft is a spiral gear driven through a key. This spiral gear drives at half engine speed another spiral gear which pilots on the hub of the cam timing flange. The latter is keyed to the idler shaft and driven by four special screws which set the valve timing through the selection of a differential series of holes in the two pieces. When the timing is set, the hub of this flange is clamped against a hardened washer which rests against a shoulder on the idler shaft and

also takes the gear thrust on the flange of the bronze bushing in the gearcase. The clamping is done by a special nut provided with a drive for a tachometer cable. At the opposite end of the idler shaft is a gear meshing with the gear which is an integral part of the cam. The idler shaft bushings are lubricated by a pressure line in communication with the annular space between the cam drive shaft bushings. Above and at right angles to the cam drive shaft lies the magneto drive shaft.

Gearcase Cover.—The cast aluminum cover which closes the opening at the rear of the gearcase is located by two dowels and held in place by eight studs. In addition to the three long studs in the gearcase, three other studs are fixed in the cover to permit either the mounting of an electric starter or the cover which closes the opening central with the crank axis.

In line with the idler shaft axis, a special stud is screwed and locked in the gearcase cover to provide a means of attaching a standard tachometer connection. The breather, which is cast integral with the cover, has baffles to retain oil spray and a conical screen at the outside opening to keep out dirt.

Oil Pump.—The oil pump is built up of three main units: a lower body, an upper body, and a plate. In the upper body are the pressure gears, the driver being integral with the oil pump shaft at whose upper end is mounted a spiral gear which meshes with the large half engine speed gear. The idler pressure gear is bronze and it turns about a bolt which is used to tie the pump together. Oil enters the pressure pump through an opening in the plate and lower pump body. As it leaves the pressure pump, the oil must pass through a cylindrical screen of fine mesh, which is held between the upper body and plate. Once through the screen, the oil can enter the drilled openings in the gearcase which lead to the bearings or to the pressure relief valve.

Below the plate in the lower housing are the wider gears for scavenging. The driver is steel and it fits over a square on the drive shaft. The driven gear is bronze and it centers on the same tie bolt as the pressure driven gear above. Oil enters the cylindrical opening in the gearcase surrounding the pump through the hollow dowel which is used to locate the gearcase. It must pass through a coarse mesh brass screen before entering the gears.

The pressure and scavenging oil connections for the lines to the outside oil tank are alike. A hollow stud draws the bronze connection up against

the lower body, a copper asbestos being used above and below. These connections may be turned in any convenient position for the oil lines.

Excess oil from the pressure pump passes through a relief valve and re-enters the inlet side of the gears. The desired oil pressure may be obtained by screwing in or out the adjuster located at the lower rear of the lower pump body. The adjuster guides the relief valve, the latter being hollow to serve as a guide for the coil spring. The two oil connections, studs, the adjuster, as well as the two long screws, which help hold the three sections of the pump in a single unit, are all safetied by lock wires.

SPECIFICATIONS

Model.....	5-D
Manufacturer's rating.....	60 horsepower at 1,900 r.p.m.
Approved rating.....	65 horsepower at 1,950 r.p.m.
Number and arrangement of cylinder.....	Five-radial
Cooling.....	Air
Bore.....	4.125 inches
Stroke.....	3.750 inches
Total piston displacement.....	250.58 cubic inches
Compression volume ratio.....	5.42:1
Overall diameter.....	32 $\frac{3}{4}$ inches
Overall length.....	22 $\frac{1}{4}$ inches
Dry weight, complete.....	222 pounds
Crankshaft:	
Journal diameter.....	1.9684 inches
Crankpin diameter.....	1.750 inches
Propeller Hub:	
Type.....	Taper, key and nut
Dimensions—Body diameter.....	2.689 inches
Between flanges.....	4.0625 inches
Diameter bolt circle.....	4.625 inches
Number bolts.....	Six
Diameter bolts.....	.437 inches
Valve tappet clearance—cold.....	0.015 inch
Valve tappet clearance—hot.....	0.035 inch
Designed Timing Engine (hot):	
Inlet open.....	0°
Inlet closed.....	60° late
Exhaust open.....	60° early
Exhaust closed.....	0°

Cam:	
Type.....	Single ring—three lobes
Speed.....	One-sixth crankshaft speed
Direction of rotation.....	Same as crankshaft
Carbureter:	
Make.....	Stromberg
Model.....	NA—R3
Altitude mixture control means.....	Main jet needle control
Air heater.....	Special equipment
Ignition:	
Type.....	Dual—magneto
Make.....	Scintilla
Model.....	PN—5D
Speed of rotation.....	1¼ crankshaft
Spark timing.....	Fixed—25° advance
Lubrication:	
Type.....	Full pressure, dry sump
Oil pump.....	Gear type—1 pressure 1 scavenging
Speed of oil pump.....	1½ crankshaft speed
Oil flow at 2,000 r.p.m.....	3 pounds per minute
Oil consumption.....	0.013 pounds per horsepower- hour

CHAPTER 7

THE VELIE M-5 ENGINE

The Velie five-cylinder engine is of the air-cooled radial type, as shown in Figs. 1 and 2, the small size being designed to develop 54 horsepower at 1,800 r.p.m. and 62 horsepower at 2,000 r.p.m. The engine has a two-piece crankshaft supported on three ball bearings and a solid master connecting rod. The main crankcase is in one piece and has the lugs for mounting integral with it. The gearcase cover carries the magneto, oil pump, and tachometer drive. The crankshaft and rod assembly is shown in Fig. 3. The main rod is babbitt bushed while the small, or link rods, have bronze bushings at both ends. The cylinders are of nickel steel castings with the fins cast in place and the heads are of aluminum alloy, shrunk into place. The valves seat on an aluminum bronze bushing. A sectional view of the engine is seen in Fig. 4. The essential dimensions and other information follow:

Propeller drive.....	Direct
Rated h.p.m. at sea level.....	54-1,800
Maximum horsepower and r.p.m. at sea level..	62-2,000
Weight dry without hub or starter.....	225
Weight per rated horsepower.....	3.63
Bore and stroke, inches.....	$4\frac{1}{8} \times 3\frac{3}{4}$
Compression ratio.....	5.2
Displacement, cubic inches.....	250.6
Diameter of mounting.....	$12\frac{3}{4}$
Height or overall diameter, inches.....	32
Length without starter, inches.....	27
Fuel consumption at rated horsepower LB- HP-HR, pounds.....	0.55
Oil consumption LB-HB-HR, pounds.....	0.025
Valve mechanism.....	Push rods and rocker arms
Intake valves per cylinder.....	1
Exhaust valves per cylinder.....	1

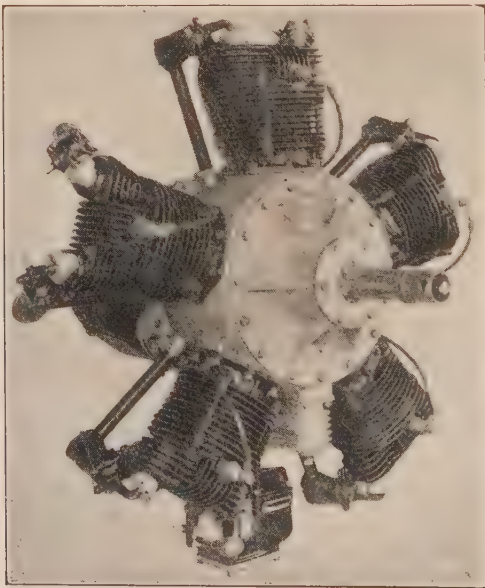


FIG. 1.—Front end of Velie five-cylinder engine.

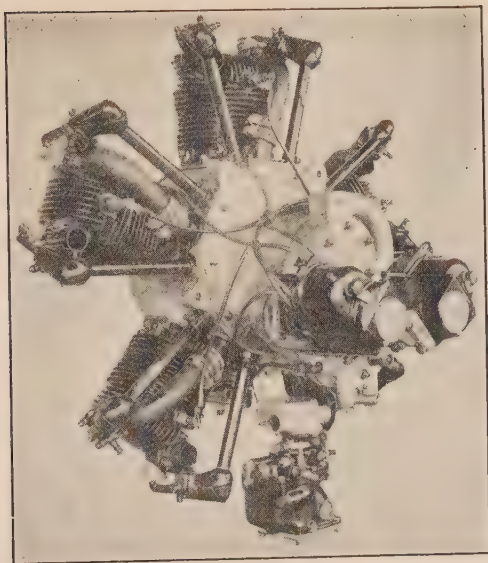


FIG. 2.—Rear view of Velie engine.

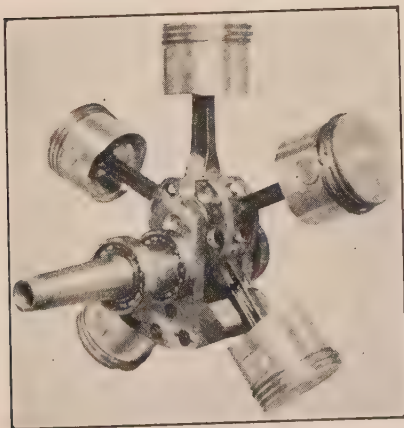


FIG. 3.—Crankshaft and rod assembly.

Two oil pumps are used in the force-feed lubricating system. The outer or pressure pump draws oil from the supply tank and delivers it under pressure to all gear shaft bearings, and through the drilled crankshaft to the master connecting rod and small rod bearings in the main rod. Piston pins, cylinder walls, and crankshaft ball bearings are lubricated by oil sprayed from the master connecting and small rod

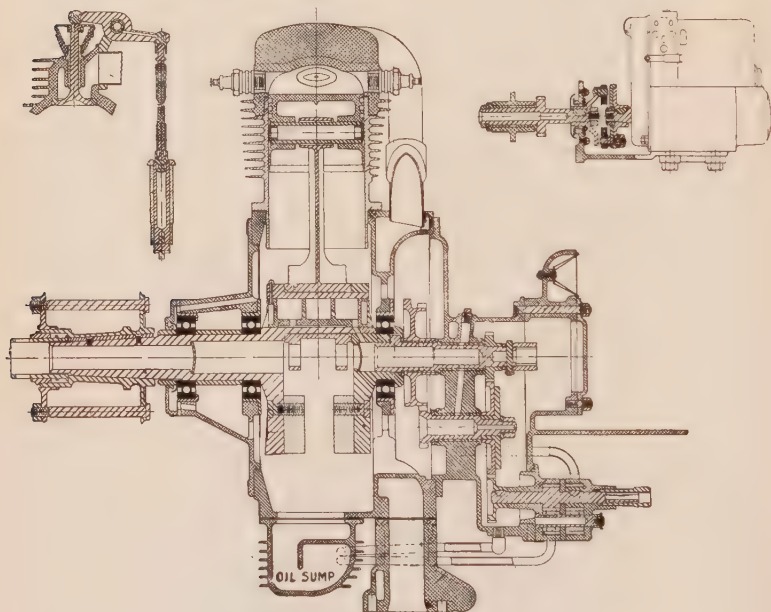


FIG. 4.—Section view of Velie engine.

bearings. Excess oil drains into a sump, with fins on the outside for cooling, and this oil is returned to the supply tank by the inner or scavenging pump. Oil pressure is regulated by a relief valve in the pressure pump and should never drop below 60 pounds when engine is running at top speed. Oil temperature in the sump, as shown on the dash, should run between 110 and 150° F. and never exceed 180° F. Rocker arms require grease after every 5 hours of running.

CARE OF VELIE ENGINES

To secure long life and satisfactory service the makers recommend inspection and servicing of the engine after 5 hours of flying. The following suggestions will aid in making such inspections.

Remove and clean all spark plugs and at the same time check each electrode gap. Electrode gap should be the same on all spark plugs and set 0.018 to 0.020 inches on AC plugs and 0.015 on B.G. plugs.

Check tappet clearance. Set to 0.015 when engine is cold.

Grease rocker arms.

Oil magnetos with a good medium body oil. At the front end: 30 to 40 drops; at the back end about 10 drops. Keep the opening of the contact points at 0.012 inch. Keep the contact points clean of dirt and oil. Do not file points unless absolutely necessary due to excessive pitting. Never use emery cloth.

Never Accelerate Engine Until It Has Been Warmed Up Thoroughly.—

When the engine is started, it should be run for at least 5 minutes at closed throttle and then gradually open throttle to thoroughly warm the engine before taking off.

The proper way to stop the engine is to shut off the gasoline supply and let the engine die out from the charge in the carbureter bowl. If it is inconvenient to do so, it is advisable to let the engine idle for 5 minutes or so before cutting the switch. This will not only give the valves a chance to cool down, but also distribute oil through the inside of engine so as to have the parts well lubricated for the next start.

More airplane engines are harmed through neglect of these perfectly simple rules than any other cause. Improper stopping is the greatest source of valve trouble in aviation engines.

Check all nuts for tightness except on cylinder head bolts.

Never Disturb Cylinder Head Bolt Nuts.—The cylinder heads are shrunk and bolted on with the proper tension in the shop and are not removable.

Disassembling the Engine.—To disassemble the engine for inspection or repairs proceed as follows. This should not be attempted by anyone except an experienced mechanic.

(SPECIAL NOTE.) Do not attempt to remove cylinder heads from cylinders.

1. Place engine on suitable stand with propeller or front end down.
2. Remove exhaust ring.
3. Remove push rods.
4. Remove carbureter adapter and oil sump.

5. Remove spark plugs and pull cylinders after removing nuts from cylinder and intake flanges. Do not disturb rubber intake tubes unless they are to be replaced.

6. Push or tap out piston pins and remove pistons.

7. Remove magnetos, magneto couplings, and oil pump. Then the gearcase cover. (NOTE. Gearcase, gearcase cover, magnetos and oil pump can be removed as an assembly if no work is to be done on them.)

8. Remove gearcase assembly. Remove valve lifters and roller if desired.

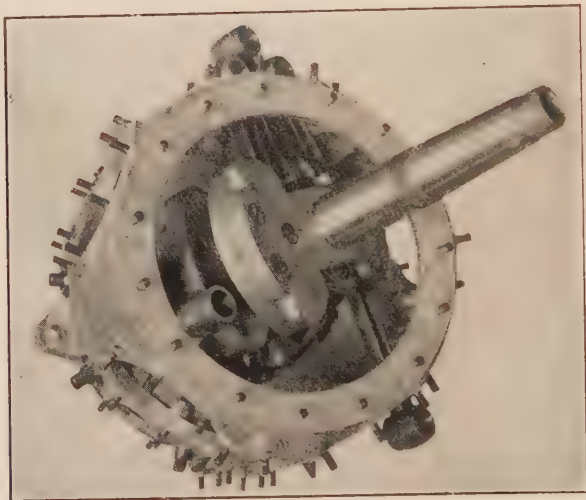


FIG. 5.—Removing crankshaft and connecting rods.

9. Turn engine over with propeller or front end up.

10. Remove propeller hub key, front thrust-bearing cover, front bearing nut and oil sling. Now pull the crankcase cover.

11. The crankshaft and master-rod assembly can now be removed. First raise the assembly until the rear ball bearing is out of its sleeve. Then rotate crank until Nos. 1, 2, and 5 rods can be inserted into No. 1 cylinder opening. Now move whole assembly over until No. 4 rod will tip through front opening and then lift out the assembly. (See Fig. 5.)

12. To remove connecting rod assembly, take out clamp bolt in crankshaft rear half and tap off from crankpin. The rod assembly is now free to come off.

13. To remove connecting rod links from master rod, remove wristpin lock screws in master-rod flange and tap out wristpin. This should not be necessary until after at least 250 hours and should not be disturbed then unless bearings show excessive looseness.

14. The gearcase assembly should not be disturbed unless gears are damaged or bearings show looseness. If gear shafts or bushings are renewed it should be seen that they have a free running fit and from four to six thousandths end clearance.

ASSEMBLING THE ENGINE

Before assembling the engine, clean all parts thoroughly with gasoline and scrape off carbon from top of pistons and inside cylinder heads.

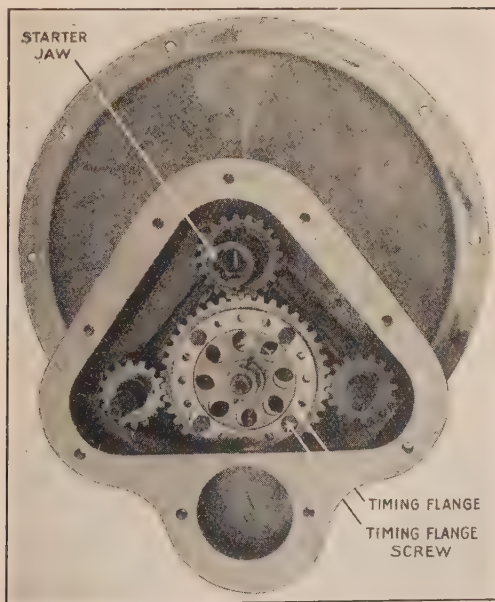


FIG. 6.—Timing gears and starter clutch.

To assemble engine, reverse operations used in disassembling. Oil all moving parts before they are assembled to engine. Be sure that all nuts and screws are tight and see that cotter pins, lock washers, and safety wires are not missing.

Valve Timing.—To time the valves proceed as follows:

First rotate crank until No. 1 piston is at top dead center. This can be observed through the spark-plug hole. The propeller hub key will now be in line with center line of No. 1 cylinders. Now, with gearcase cover removed, remove the four screws in the gear timing flange (see Fig. 6) and rotate flange until No. 1 exhaust valve is closed and valve lifter is on low point of cam. Now set tappet clearance on No. 1 exhaust valve to (0.035 inch). Then rotate timing flange anticlockwise until No. 1 exhaust valve just closes. Now replace four screws in holes in flange that match up with holes in gear and secure with safety wire. After all tappets are set with fifteen-thousandths clearance the valves are properly timed.

Ignition Timing.—Engine fires 1-3-5-2-4.

Engine is timed to fire 30 degrees ahead of center or when propeller hub key is in line with a point $3\frac{1}{8}$ inches ahead of center line of No. 1 cylinder when measured on the outside of front cover flange.

To time magnetos proceed as follows:

Turn engine in direction of rotation until No. 1 piston is coming up on compression and stop when crank is 30 degrees ahead of top dead center. Loosen the three nuts on the magneto coupling. Remove distributor blocks. Turn magneto until marks on large distributor gear coincide with marks on front end plate. Now tighten the three nuts on magneto coupling. The magneto is now timed.

Cable Connections.—The cable connections from the distributor blocks to the spark plugs are as follows:

Number 1 cable from magneto block connects to spark plug in No. 1 cylinder, No. 2 cable to spark plug in No. 3 cylinder, No. 3 cable to spark plug in No. 5 cylinder, No. 4 cable to spark plug in No. 2 cylinder, and No. 5 cable to spark plug in No. 4 cylinder.

Before attempting to start engine be sure that ground wires are securely connected.

CHAPTER 8

THE WARNER SCARAB ENGINE

The Scarab engine is a seven-cylinder radial built by the Warner Aircraft Corporation, Detroit, Mich. It is rated at 110 horsepower at 1,850 r.p.m., the front or propeller end being shown in Fig. 1. The crankcase is of aluminum in two parts (Fig. 2), held together by through bolts and also by the bolts in the cylinder flanges. The cylinder numbers are cast on the front half of the case (Fig. 1), which shows No. 1

at the top and the numbers running counter-clockwise, from the propeller end, as the engine runs.

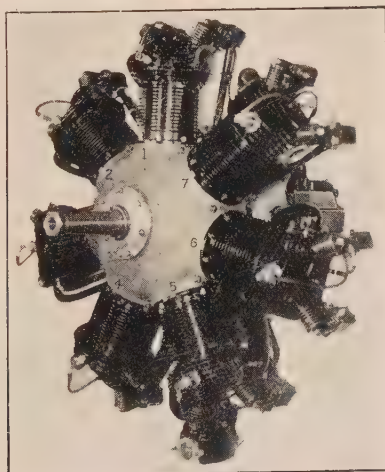


FIG. 1.—Front end of Scarab engine.

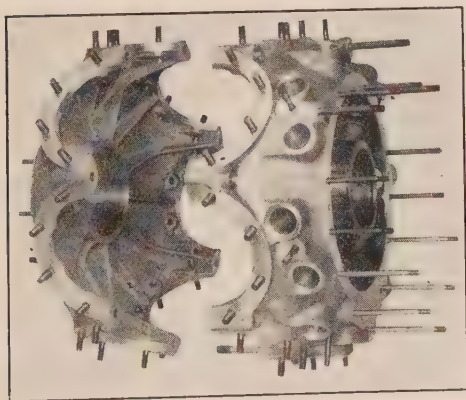


FIG. 2.—Both halves of crankcase.

The ball-bearing crankshaft is shown in Fig. 3 with the bronze counterweights in place. The connecting rod is of the split type with one

small rod each side of the main rod. The cap carries four small rods. Both ends of each small rod pin bear in bronze bushings in the flanges of the main rod and cap. The piston ends of the rods are also bronze bushed. The main bearing on the crankpin is of babbitt. See Fig. 8.

The cylinder barrels are of alloy steel with a cylinder head of aluminum alloy shrunk in place and bolted the cylinder barrel. Valve guides and bronze valve seats are shrunk into the cylinder head. Rocker-arm housings are separate aluminum castings bolted to the cylinder head. The rocker arms of the 1928 engines have bronze bearings, but ball bearings are used in the 1929 model.

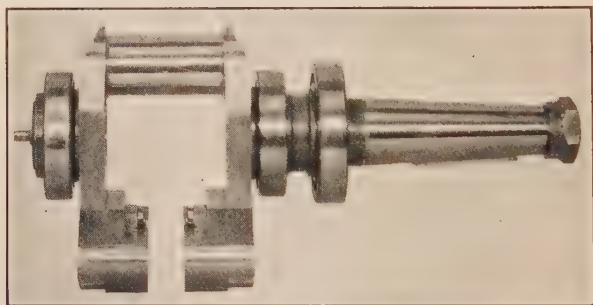


FIG. 3.—Solid one-piece, ball bearing crankshaft.

The cam ring is drop forged of alloy steel, case hardened on all wearing surfaces. Intake and exhaust surfaces are side by side, and revolve at one-eighth crankshaft speed. A pressure pump delivers oil to all plain bearings. The oil forced out of these bearings lubricates all other moving parts and collects at the bottom of the crankcase, from which it is drawn by a scavenger pump and delivered to the oil tank through a strainer. The gearcase carries two magneto drives which are arranged to permit the mounting of a starter between them.

GENERAL SPECIFICATIONS

Type.....	Static, radial, air cooled
Number of cylinders.....	7
Cycles.....	4
Bore.....	4 $\frac{1}{4}$ inches
Stroke.....	4 $\frac{1}{4}$ inches
Piston displacement.....	422 cubic inches

Compression ratio.....	5.2:1
Normal speed.....	1,850 r.p.m.
Rated power at 1,850 r.p.m.....	110 horsepower
Direction of rotation of crankshaft (looking at propeller end).....	Anticlockwise
Tachometer shaft speed.....	$\frac{1}{2}$ crankshaft
Rotation of tachometer shaft (looking from the rear).....	Anticlockwise
Weight dry without hub or starter.....	275 pounds
Specific weight.....	2.5 pounds per rated horsepower
Ignition.....	Dual scintilla M N 7—D clockwise
Magneto timing (full advanced).....	32° B. T. C.
Magneto breaker gap.....	0.012 inch
Carburetion.....	Stromberg single barrel 2-inch carbureter
Spark plugs.....	A. C. Aviation (18 MM—1.5 MM Pitch thread)
Spark-plug gap.....	0.021 inch
Guaranteed fuel consumption at rated power.....	0.55 pounds per horsepower-hour
Guaranteed oil consumption at rated power.....	0.025 pounds per horsepower-hour
Valve-tappet clearance, when cold.....	0.010 inch
Valve-tappet clearance, when timing...	0.027 inch
Valve timing (at 0.027 tappet):	
Inlet opens.....	10° B. T. C.
Inlet closes.....	60° A. B. C.
Exhaust opens.....	60° B. B. C.
Exhaust closes.....	10° A. T. C.

Installation Dimensions

Overall length without starter.....	29 inches
Overall diameter:	
1928 Series.....	35 $\frac{1}{2}$ inches
1929 Series.....	36 $\frac{1}{4}$ inches
Distance from mounting to C. L. of cylinders.....	62 $\frac{9}{32}$ inches
Distance from mounting to rearmost point.....	91 $\frac{9}{32}$ inches
Diameter of mounting bolt circle.....	17 inches
Mounting bolts.....	10-5 $\frac{1}{16}$ S. A. E.
Oil lines to tank.....	$\frac{5}{8}$ inch O. D. tubing
Gasoline lines.....	$\frac{5}{16}$ or $\frac{3}{8}$ inch O. D. tubing

INSTALLATION

The engine is shipped bolted to a steel plate. Before the engine is mounted in the plane inspect the bolt bosses on the mounting ring for flatness. Where a detachable engine mount is used this can be easily done by laying it on a surface plate. Variation in flatness of over $\frac{1}{64}$ may be taken up using wood-veneer washers. All of the ten mounting bolts should be used. They are of alloy steel and ordinary bolts must not be used.

The engine is equipped with a 2-inch Stromberg carbureter. A strainer should be placed between fuel tank and carbureter. There should be a minimum fuel head of 20 inches between the bottom of the tank and the carbureter when plane is standing on the ground. Only gasoline hose that corresponds to Air Corps specifications would be used. All fuel and oil lines should be of seamless copper tubing, heated and quenched after bending.

The oil tank should have a capacity of approximately 5 gallons and should be located near the engine so that its lowest point is slightly above the oil pump when plane is standing. A $\frac{5}{8}$ -inch 18-thread tapped hole should be provided in the oil-tank wall, close to the bottom, for thermometer connection. If, however, no thermometer is placed in the tank, one should be installed in the oil-sump housing cover next to the carbureter, in place of the oil-drain plug. The thermometer should have a range of from 100 to 220° F.

When the oil tank is full it should have an air space of about 20 per cent of its volume. In other words, a 5-gallon tank should never contain more than 4 gallons of oil.

Ignition is provided by two Scintilla aircraft magnetos. Where a booster magneto or booster coil is used for starting, a 7 mm high-tension wire should be used to make connection from it to the trailing terminal marked "H" on either one of the two magnetos.

Never turn the propeller when there is gasoline in the carbureter, unless all magnetos are grounded. The ignition switch must be "off" and all ground wires must be tightly connected to the terminals. This is the only sure safeguard against accidental starting of the engine.

INSPECTION

AFTER FIVE HOURS OF FLYING

Grease rocker-arm shafts by means of the grease gun, with plain cup grease of good quality.

On engines with plain rocker arms, **grease ball ends of push rods**, after removing rocker-arm housing covers, with a mixture of grease and graphite or with Dixon's No. 677 Graphite Grease. On engines with ball-bearing rocker arms, the push-rod ball end is greased simultaneously with the rocker-arm bearing through the Alemite fitting and does not need special attention.

Check tappet clearances, which should be 0.010 inch for the intake and exhaust valves when the engine is cold. Proceed as follows: Turn the propeller forward until the intake valve on cylinder 1 closes, then turn propeller an additional 120 degrees (one-third of a full turn), which brings the piston to top center. Insert the feelers between the valve stem and the rocker-arm roller, for measuring. Make adjustment if the clearance is found to be below 0.010 or above 0.012 inch. On an engine of the 1928 series, adjustment is made by loosening the clamp screw in the rocker arm and by turning the ball socket with a screwdriver. Do not forget to tighten the clamp screw after adjusting. On the 1929 series, the clamp screw is replaced by a locknut on top of the ball socket. When cylinder 1 has been adjusted, turn the propeller forward 120 degrees beyond the closing of intake valve on cylinder 2, then check the clearance of this cylinder. Continue this procedure all around until all tappets are checked and adjusted. There are four cams on each cam ring surface with four low base surfaces between them. If in checking cylinder 1 it should be found that the clearance is considerably more than that specified on **both** valves, it is advisable to turn the propeller exactly two full turns forward, which brings the next cam base into action. Check the tappet clearance again. By repeating this operation three times the cam base having the least tappet clearance will be found, and this base should be used to check the clearance of the tappet on all other cylinders when proceeding as indicated above.

AFTER FIFTEEN HOURS OF FLYING

Drain oil by opening the petcock or plug at the bottom of oil tank and by removing the drain plug at the bottom of the engine. The tank and the engine may be flushed with clean light oil if grit is found in the old oil.

Remove oil screen at the left side of the engine, by unscrewing the acorn nut and pulling out the cover with the screen. Wash it in clean gasoline but do not replace it in the engine before it is completely dry.

Fill oil tank 80 per cent full with approximately 4 gallons of oil of the quality specified in "Starting and Operation," after the screen and all the plugs have been replaced and have been secured with lock wire wherever provision is made for it.

Clean gasoline strainer if one is installed, making sure not to trap any air in the strainer. Open the gasoline petcock and then close strainer tightly after it has been observed that gasoline is leaking out of the strainer.

Oil the magnetos especially on the drive end, with a good grade of light engine oil; at the same time oil all the moving joints of the spark, mixture, and throttle controls.

Tighten all the nuts and bolts, immediately replacing cotter pins and lock wires when they have been removed for any purpose. Great care should be taken not to forget the propeller hub bolt nuts if a wooden propeller is used, the thrust cover nuts behind the propeller hub, all the nuts in the rear of the engine, and the mounting bolt nuts. The intake pipes are made from aluminum; therefore, the bolts or nuts holding them to the cylinders should not be tightened excessively, as this will deform the flanges and cause leaks.

Check throttle, mixture, and spark controls, making sure that the full movement of the controls in the cockpit corresponds to the full movement of the controls at the engine. Adjustments may be necessary where wires and springs are used to make the control connections.

Check the ground wire and switch-wire connections at the engine and at the switch. It is very important to see that these connections are tight and that there are no breaks in the wires. This is to prevent accidental starting of the engine should the propeller be turned while the ship is standing on the ground with the ignition switch set to "Off."

Check all high-tension wires, to be certain that they are not being chafed anywhere by sharp edges.

Examine all spark plugs for cracks in the insulation. These are usually caused by rain. Wipe the insulation clean, but do not remove plugs unless there are indications that they are not functioning properly.

Inspect valve gear in regard to springs, rocker arms, etc. The rocker arms and the rollers at their ends must move freely and show no signs of sticking.

TOP OVERHAUL

By top overhaul is meant the grinding of valves and the making of necessary adjustments on the cylinders. If an engine has been properly taken care of, this should not be necessary before 100 to 150 hours or more of flying.

The need for a top overhaul is usually indicated by the inability to get the required engine speed on the ground with full open throttle. It will be found that the propeller speed will vary with the air temperature and the barometric pressure; but a drop in speed of more than 100 r.p.m. may be taken as an indication of the need of a top overhaul.

Before testing the ground speed for the purpose of determining the necessity of a top overhaul, make the following checks and adjustments. Be sure that the mixture control lever on the carbureter is in the full-rich position when the control lever in the cockpit is in the corresponding position. Check the spark advance lever on the magnetos in the same way. With the feeler gage, check the magneto breaker gap, which should be 0.012 inches, and at the same time check the valve and magneto timing, in accordance with instructions given under "Complete Overhaul." Be sure that the fuel flow to the carbureter is not obstructed. If the oil pressure is below 60 pounds per square inch at 1,800 r.p.m., inspect the relief valve to see that it is clean and free from burrs. Replace the valve spring with a new one, if necessary. The relief valve is located in the rear of the engine, just below, and to the right of the oil pump, and it can be screwed out after removing the lock wire.

Disassembling.—A top overhaul can readily be made without dismounting the engine from the plane, with the tools found in the tool kit furnished with each engine. After removing the propeller, the cowling and the exhaust pipes, clean the outside of the engine with gasoline. *On account of the fire hazard, do not attempt to wash the engine before it has thoroughly cooled off.*

Remove the rocker arm socket and pull out the push rod. Then apply the valve-supporting tool through the spark-plug hole, and depress the springs with the tool shown in Fig. 4, thereby unlocking the spring washer.

During the following disassembling, be careful not to let dirt or washers, etc., fall into the engine, as this may cause serious damage.

If new gaskets are not available, be careful in removing the old ones, and immediately place them between two wooden covers, to prevent their drying and cracking. Disconnect all ignition cables from the spark plugs and pull them through the rubber rings with which they are held to the push-

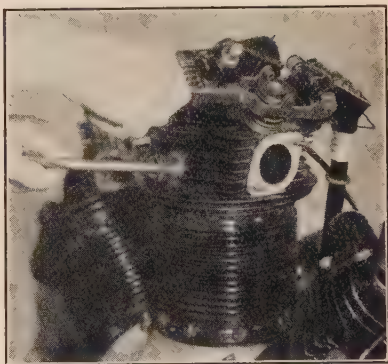


FIG. 4.—Replace the valve springs.

rod tubes. To facilitate reassembling, mark each cable as it is taken off the cylinder. Remove all spark plugs and rocker-box covers. Unscrew the two capscrews or nuts with which each intake pipe is attached to the cylinder, and remove all intake pipes. The cylinders are detached by unscrewing the eight nuts nearest the crankcase pad, with tool No. FA-33. The two rear nuts are the most difficult to reach and should be removed first. *Under no circumstances should the nuts be removed at the joint between the cylinder barrel and the cylinder head, as this is a permanent joint.*

Remove the cylinders, push rods, and push-rod tubes from the engine in numerical order, beginning with cylinder 1. The master rod is assembled into this cylinder. In performing this operation, great care must be taken that the pistons do not drop against the crankcase and become marred or dented. As each cylinder is taken off, push out the piston pin immediately and remove the piston. All parts so dismantled from the engine should be laid on a clean bench in the order in which they are removed.

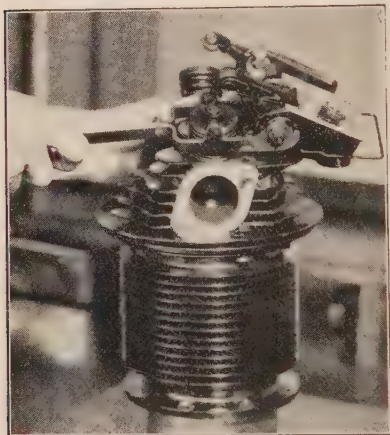


FIG. 5.—Removing the valve springs.

While overhauling the cylinders, wrap a piece of cloth around the engine for protection against dust and dirt.

On the 1928 series of engines, the rocker arms should be removed next; but the rocker boxes should be left attached to the cylinders.

Before removing the arms, they should be checked for play, and where this is found to be excessive, they should be replaced by new arms. The old arms may be returned to our factory for rebushing and reaming. On the 1929 series, it is not necessary, nor is it desirable, to remove the rocker arms in order to grind the valves, and they should be taken apart only when some part is damaged or broken. It should be determined which valves are leaking and need grinding. This is done by pouring gasoline into the valve port.

To remove the valves which leak, place the cylinder over a smooth wooden block. This block should be $4\frac{1}{8}$ inches in diameter, 9 inches high, and rounded at its upper end, to fit, approximately, the cylinder dome. It is best to have the block attached to a wooden base, so that it stands upright on the work bench. This block serves to hold the valves closed

while the springs are being removed. Depress the valve springs with tool, as illustrated in Fig. 5. Remove the split cone, the valve washers, and the springs; then take off the circlip which is snapped into a groove in the valve stem. This circlip must be removed and assembled from the side and it should never be pulled over the end of the valve. To avoid damaging the valve guide when pulling out the valve, inspect the stem end for burrs. If any are found they must be removed.

Reconditioning and Valve Grinding.—After both valves have been removed, scrape off all carbon from the cylinder dome and from the valves, being careful not to mar or scratch the valve seats and the valve stem.

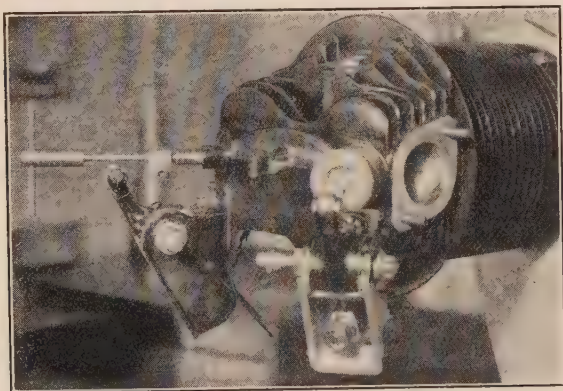


FIG. 6.—Grinding the valves.

The carbon should also be scraped off the top surface of the piston, which should afterward be laid on a surface plate and smoothed with a piece of kerosene-soaked crocus cloth. Inspect the piston for cracks and check the piston pin for proper fit in both the piston and connecting rod. Check the piston rings for gap and side clearance in the grooves, according to the table of clearances given on page 245.

If there are any sharp edges or scratches on the pistons or in the cylinder-wall surfaces, they should be carefully removed by stoning with a fine grade oil stone. Inspect to determine whether all push-rod ball ends are tight on the rods.

To grind the valves, spread a small amount of grinding compound all around the seat of the valve, insert the valve in place and grind with tool as in Fig. 6. Repeat this operation until a good seat is obtained, then wash

the valves and cylinder carefully with gasoline, so that no trace of grinding compound remains.

A simple and handy fixture for holding the cylinder, while grinding the valves or cutting the valve seats, is a 6- by 12-inch steel plate, $\frac{3}{8}$ inches thick, with a $4\frac{1}{2}$ -inch diameter hole near one end. The cylinder should be attached to this plate with two $\frac{5}{16}$ inch diameter bolts holding the cylinder flange to the plate; the other end of the plate should be clamped in a vise.

Assembling.—Before assembling, be sure that all parts are absolutely clean and in good condition. As the parts are being put together, oil all bearing and other contact surfaces generously.

Put the valves in place, being careful not to interchange those of different cylinders. The cylinder number is etched on each valve stem, just below the groove. Put the cylinder over the wood block used for disassembling, snap the circlips into their grooves and assemble the lower valve spring washer, the springs, and the upper washer to the head. Depress the springs with tool, and assemble the two halves of the split cone retainer. Be sure that the two halves used on each valve bear the same number.

After the valves have been assembled, they must be inspected with gasoline for tightness, and if they are still leaking, the entire procedure must be repeated until they are tight. When the valves are tight, assemble the rocker arms, in cases where they have been removed. The cylinders are now ready to be replaced on the engine.

Inspect all crankcase pads for burrs and place the cylinder gaskets on the pad. On each piston, starting with piston 1, space the piston-ring gaps 120 degrees apart, assemble the piston with the number stamped on the top surface toward the propeller end, and push the piston pin in place, with all the marked ends in the same direction.

Before attempting to assemble the push-rod tubes and push rods to the engine, turn the crankshaft so that both camfollowers are in their bottom position. After the entire piston has been oiled generously, clamp the tool over the piston rings. Put a new packing on each end of the push-rod tubes if necessary, and, in addition, there must be a cable ring on each tube of cylinder 1. On the 1929 series of engine, assemble a steel washer between the packing and the shoulder on the inner end of the tube. On the outer (longer) end, assemble the spring, the washer, and the packing, in the order mentioned.

The push rods are placed into the tubes with the marking toward the rocker arm. The rods are marked alphabetically, starting with "A" for the exhaust side of cylinder 1 and following around the engine clockwise, when viewed from the rear.

The cylinder, with its wall generously oiled, is then slipped over the piston. As soon as the rings are inside the cylinder, the clamping tool must be

removed; and, as the cylinder is pushed further in, great care must be taken in guiding the push rods and tubes into the rocker boxes. Be sure that the spring bail for the rocker-box cover is outside the push-rod tubes. After the cylinder is on, fasten it to the crankcase with the eight nuts and lock washers.

After cylinder 1 has been assembled to the crankcase all the other cylinders must be assembled in numerical order in the same way. Note that on cylinders 2, 3, and 4, only the exhaust push-rod tubes require cable attaching rings, and on cylinders 5, 6, and 7, this ring is put on the intake push-rod tubes only.

If the engine has been in use for any length of time, new rubber packings should be used on the intake pipes every time one is removed, as the old packings may be difficult to assemble and will not hold tight. Dip the intake pipe gasket in castor oil to warrant a perfect seal and put it on the intake flange of the cylinder. Assemble the spring, the gland (with the flat surface toward the spring), and the packing, to the intake pipe; press the latter into the induction housing, and fasten it to the cylinder.

Set all valve-tappet clearances to 0.010 inches, by following instructions given on page 242 and put on the rocker-box covers. Check the gap on all spark plugs. This should be 0.021 inch. Next, screw plugs in place. Care must be taken to be certain that there are no burrs on the threads. If a plug does not screw freely into the head, it should not be used, as it will damage the aluminum thread in the cylinders. Next, replace all ignition cables.

It is not necessary to time the valves or the ignition after a top overhaul.

COMPLETE OVERHAUL

When an engine has been in service 350 to 500 hours and has been top overhauled once or twice, it should be completely overhauled. This will be needed after a still shorter period of service unless the engine has had good care in maintenance and operation. A complete station tool equipment, is required for a complete overhaul. On account of this it will, in many instances, be found more economical to return the engine to the maker for a complete overhaul.

Complete Disassembling.—To disassemble an engine completely, it must first be removed from the plane. Block the wheels of the ship, then remove the cowling, the propeller, the exhaust pipes, and the carbureter heater, if one is installed, and disconnect the oil, gasoline, tachometer, and all gage connections. Also remove the long oil line (scavenger) at the rear of the engine. Support the engine at the two lifting eyes back of the top cylinder, by means of a pulley. Remove the ten $\frac{5}{16}$ -inch diameter mounting

bolts and hoist the engine from the plane, carefully clearing the magnetos and other accessories in the rear.

Place the engine on an assembly stand and attach it to the frame with from four to six bolts. Clean the outside of the engine thoroughly with gasoline before attempting to disassemble it.

All small parts should be placed in clean pans or boxes and all gaskets placed between two wooden covers, to prevent their drying and breaking. Notes should be taken of all defects discovered during the disassembling, and the maker notified of any damage observed which is not due to normal operation. In reporting such cases, the engine number must be given.

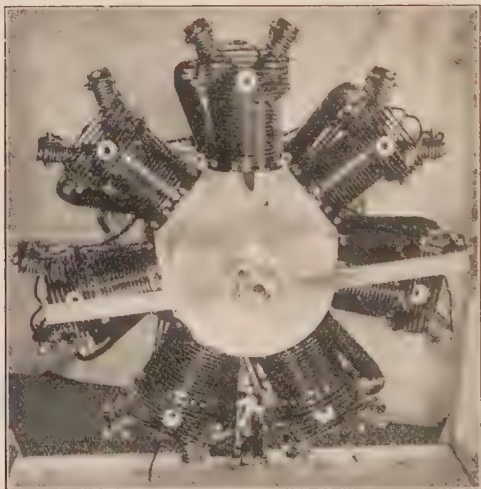


FIG. 7.—Crankshaft wrench and timing disk.

Removing Auxiliaries. Take off the ignition cables by disconnecting the spark-plug terminals from the plugs, and by removing the cable blocks from the magnetos. Next, the clips which hold the cable tubes and the cables to the induction housing should be disconnected. The cables should be slipped through the rubber rings holding them to the push-rod tubes and the whole unit with the tubes and blocks should then be taken from the engine. Remove all spark plugs and the two lock wired cap screws at each magneto drive. If these cap screws cannot be reached, turn the crankshaft with wrench, shown in Fig. 7, which should be screwed on the shaft and locked with the propeller nut. The screws holding the magnetos to their

brackets should then be taken out and the magnetos removed from the engine. Next, the two magneto-drive housings should be taken from the gearcase but these units should not be taken apart. The oil strainer and the relief valve, both of which will be found below the oil pump, are then taken off. Remove all nuts holding the gearcase to the induction housing and lift off the gearcase.

Next, remove the timing gear, which is held in place by three capscrews, and pull out the auxiliaries drive shaft just above it. The engine stand is then tilted so that the cylinders are in a horizontal position with the propeller end upwards.

Remove the intake pipes, cylinders, and pistons and disassemble the valves, as per instructions under "Top Overhaul."

Removing Crankcase Front Half.—Remove the lock ring from the thrust-bearing nut and hold the crankshaft with wrench. Unscrew the thrust-bearing nut with spanner wrench. The thrust-bearing cover and the oil slinger immediately below are next removed.

After all gaskets have been taken from the cylinder pads, the seven crankcase nuts are removed and the six bolts through the crankcase are driven back. *Between cylinders 4 and 5, instead of a bolt there is a stud, which should not under any circumstances be driven back.* The front crankcase is now ready to be lifted off and the crankshaft and connecting rods can be lifted out as a unit. The short oil line, the oil-sump cover, and the carbureter are detached next, and the engine stand is tilted back to the vertical position of the frame. Unscrew all nuts on the rear face of the induction housing and remove the rear half of the crankcase.

Detach all camfollower crabs and take out all camfollowers, together with their guides. In order to avoid interchanging, keep each camfollower in its guide. The lock ring holding the cam gear in place is then sprung out of its groove and the cam ring is pulled off, after the end of the sleeve on which the cam ring rides has been inspected for burrs.

Disassembling Crankshaft.—The thrust-bearing spacer and front ball bearing should be pulled off only in case the ball bearing shows excessive wear and needs replacement, or if the bearing or the sleeve is loose on the shaft. *Whenever a ball bearing is replaced in the engine, use only "Aircraft Bearings,"* which are designated by red, white, and blue stripes on the package. The shaft is next clamped in a vise with copper-covered jaws gripping one counterweight (Fig. 8), and the master rod is disassembled by removing the four bolts holding the cap to the rod. The link rods should be disassembled from the master rod only in case some parts need to be replaced on account of excessive wear. If a link rod has to be removed, the wristpin locking bolt and the pin will have to be driven out.

Proceeding, turn the shaft around in the vise and remove the cotton pin, nut, ball bearing and spacer in the rear, and drive out the plug from the crankpin toward the rear after the cotter pin securing it to the cheek has been taken out. Any sediment which has collected in the crankpin plug must be washed off with gasoline. The coupling and the pin holding same should be left undisturbed in the shaft.



FIG. 8.—Disassembly crankshaft.

Inspecting and Reconditioning.—After the engine is disassembled, all parts should be cleaned in kerosene, then rinsed in gasoline, and dried. Inspect all parts on a clean bench, according to the following instructions:

Examine all castings for cracks, preferably with a large magnifying glass. On all machined surfaces, remove all burrs, as these may cause damage in operation, or prevent a joint from being tight.

Check all clearances, according to the table on page 245. If the permissible clearance is exceeded, the worn part must be replaced and wherever the old part shows any markings for assembly purposes, these must be transferred to the new parts. New parts put into the engine must be carefully fitted to the clearances specified for each case.

In replacing worn bronze bushings, the new parts must be checked as to their press fit before they are pressed into place. After they are assembled, they must be reamed in the fixture provided for this purpose in the station

tool equipment. After bushings have been reamed to the proper diameter, they must, in most cases, be faced to obtain the proper end clearance.

Crankcase and Gearcase.—The crankcase should be inspected for burrs on the parting surfaces between the two halves, and the main bearing sleeves should be inspected for tightness in the case, and for the fit of the outer races of the ball bearings.

The gearcase should be inspected as a unit with the magneto brackets and the oil pump. It is not advisable to remove the oil pump from the gearcase, unless it is found necessary to replace parts. While the gearcase is being washed in clean gasoline, the drive shaft should be turned several times in order to clean the inside of the pump.

Crankshaft and Connecting Rods.—Inspect the crankshaft for straightness, and its journals and the crankpin for roundness. Blow out all oil passages, in order to remove any fine particles of dirt, etc.

If the babbitt in the master rod shows any high spots, scrape them lightly with a sharp scraper. Inspect the bushings in all rods and replace the worn ones, following the instructions given above. Be sure that the tachometer shaft turns freely in its bushing and that the pin holding the gear to the shaft is tight.

Camfollowers and Push Rods.—Each camfollower must slide freely in its guide, according to the specified clearance. If the roller shows excessive play on its pin, the entire assembly should be replaced by a new one.

The ball ends must be tight on the push rods and be smooth and not show any wear.

Piston and Valves.—If necessary, the valves should be ground and the piston and cylinders cleaned for carbon and reconditioned according to the instructions given in "Top Overhauling."

If the valve clearance in the guide is found to be excessive, due to wear, the valve guide must be replaced, and in so doing the following instructions must be observed. Heat the cylinder head around the valve guide, by means of a blow torch, to about 300° F. Drive out the old guides from the inside of the cylinder, using tools supplied for this work. Clean off the seat and the bore for the guide in the cylinder head and inspect the new guide for burrs, the presence of which may result in damaging the head. The new guide should be cold when driven in and the temperature of the head should be around 280° F. The guide must be driven home to the shoulder, using special tools for the intake, and exhaust. If the new guide is put in immediately after the old one has been removed, it will not be necessary to reheat the heads.

After the head has cooled off, the bronze valve seats must be re-seated, using the proper tools. If, after cutting, the seat surface is wider than $\frac{7}{64}$ inch, it is reduced to that width with the 15-degree cutter, by proceeding

in the same manner as with the 45-degree cutter. After the valve seats have been re-cut, the valves must be ground according to instructions under "Top Overhaul." If the seat surface on a valve is badly pitted or grooved, the valve should be replaced by a new one.

Assembling.—After all parts are inspected and properly reconditioned, be sure they are cleaned and generously oiled on all moving surfaces as they are being put together, also that dirt does not get into the engine during the building-up process.

A lock washer must be used under all plain nuts. With all castellated nuts use a cotter pin, but no lock washer. In either case if the nut goes against an aluminum part, a plain washer must be used in addition, next to the aluminum. If the nut contacts with a steel or bronze part, no plain washer is used. Be sure to attach the cotter pin or the lock wire where they are used, as soon as the parts are put together. It is advisable to use new cotter pins and new lock wire when reassembling an engine. For lock wire, metallic belt lacing approximately 0.047 inches in diameter is recommended.

It is very important that steel cotter pins of the proper diameter and length are used in all places. The following pin sizes should be used:

For all $\frac{1}{4}$ -inch and $\frac{5}{16}$ -inch castellated nuts, $\frac{1}{16}$ inch diameter $\times$ $\frac{1}{2}$ inch length.

For rocker-arm shaft nut and magneto-drive shaft nut, $\frac{3}{32}$ inch diameter $\times$ $\frac{5}{8}$ inch length.

For propeller hub nut, crankshaft rear nut, crankcase bolt nuts and master connecting-rod bolt nuts (1929 series only), $\frac{1}{8}$ inch diameter $\times$ $\frac{5}{8}$ inch length.

For crankpin plug, $\frac{1}{8}$ inch diameter by $\frac{3}{4}$ inch length.

The connecting-rod bolts of the 1928 series engine are locked by means of special Star washers which can be procured from the engine builder.

Crankshaft and Connecting Rods.—The crankshaft and connecting rods are assembled on the bench as a unit. First drive the crankpin plug from the rear into the crankpin, and lock it to the cheek with a cotter pin of the proper size. Then assemble the rear bearing spacer, the rear ball bearing, and the nut to the shaft, in the order given, and secure with a cotter pin.

In case it was found necessary to remove them, attach Nos. 1 and 7 link rods to the master rod, and the other link rods to the cap, all according to the markings on the rods and cap. The wristpins are marked 1 to 7 on the inside of one end, which end of the pin should be assembled to the marked side of the rod. All of the wristpin bolts should be assembled with the threaded end pointing toward the master rod. Next, the master rod and the cap are bolted together over the crankpin, while the crankshaft is clamped in a vise. The marked side of the cap and all rods must be assembled toward the propeller end. The four bolts or nuts should be gone over

repeatedly and tightened equally before locking them. To the front end of the shaft, assemble the short spacer and the front main bearing if it has been found necessary to remove them for replacement. During this and the following operations, the rear end of the shaft may be rested on a bench or a wooden block with a $\frac{3}{4}$ -inch diameter hole, to clear the coupling which remains assembled to the shaft. Oil the front ball bearing generously and slip the front half of the crankcase over the shaft. Then assemble the long spacer, if it has been removed, and the thrust bearing to the shaft. The trade and size markings of the thrust ball bearing should be placed toward the rear. Next, the oil slinger is slipped on with the flat side against the bearing and the thrust-bearing nut is screwed on lightly. The cover gasket is now laid on the front face of the crankcase with the cut-away portion over the oil-return hole, the thrust bearing is oiled generously and the thrust-bearing cover is assembled to the case—with the marking "Top" toward cylinder 1.

Crankcase Rear Half.—Lay the rear half of the crankcase on a clean bench with the rear end upward. Assemble the camfollower guides and the camfollowers into the case according to their markings. The exhaust guide of cylinder 1 is marked "A," and the others follow to the right around the crankcase in alphabetical order. Attach the crabs which hold the guides in place.

It will be found that the markings on the corresponding push rods and guides are the same. Push all camfollowers into their guides as far as possible, then slip the cam disc over the sleeve with the cam side toward the crankcase, and lock it with the retaining ring. The flat side of the ring must be toward the cam ring. Be sure that the six crankcase bolts are in place with one lifting eye under the head of each of the two upper bolts and a plain washer under the head of the four remaining bolts.

Main Assembly.—Attach the induction housing to the assembly stand with from four to six bolts through the mounting lugs. It is advisable to close the seven openings for the intake pipes with wooden plugs or rags, in order to prevent dirt and small parts from getting into the engine during the assembling.

The frame of the stand should now be placed in a vertical position. Be sure that the tachometer gear is in place and secured to its shaft by a taper pin, with the split end properly spread. Assemble the idler shaft from the front end, press the Woodruff key into the slot, and drive on the timing gear hub. Attach the oil-pump coupling to the rear of the shaft, by means of the through bolt. The rear half of the crankcase with gasket is next attached to the induction housing.

The frame of the assembly stand is now turned to the horizontal position and the carburetor with gasket is attached to the oil sump. The gasoline

inlet of the carbureter should point toward the rear. The oil-sump cover and the oil screen with a gasket on either side of it are next attached to the sump.

Oil the rear bearing of the crankshaft, to which the connecting rods and the front crankcase are already assembled, and lift the whole unit into the rear case. Cylinder pad marked 1 must be diametrically opposite the carbureter. In order to line up the cylinder pads, attach temporarily any two cylinders opposite each other with a few nuts to each half of the case. Drive the six crankcase bolts through the front half of the case and clamp the two halves firmly together with the seven nuts. Remove the two temporarily attached cylinders and screw the special crankshaft wrench on the end of the shaft and lock it with the propeller nut. Tighten the thrust-bearing nut with a wrench and a hammer, while holding the shaft from turning, with the special wrench attached to it. Now turn the crankshaft a few times to be certain that the thrust-bearing nut clears the cover, then lock the thrust bearing to the crankshaft by means of the retaining ring.

Assemble the short oil line with the gaskets, attaching the crankcase end first, then put the cylinder gaskets on the crankcase pads. Assemble the pistons, push rods, cylinders, and intake pipes, according to the instructions given under "Top Overhaul." Turn the frame of the assembly stand to a vertical position, and push the auxiliaries drive shaft into its bushing in the induction housing.

Valve Timing.—Whenever the cam drive has been taken apart, the valves must be retimed, as follows: Turn the idler shaft to get the valves in cylinder 1 in the position corresponding to firing top center, in which position both valves of this cylinder are fully closed, while No. 7 intake and No. 2 exhaust valves are both halfway open. Set both rocker arms of cylinder 1 to a tappet clearance of 0.027 inch. Attach the timing disc assembly and wrench (Fig. 7) with the propeller nut to the crankshaft. The key on the crankshaft taper is machined exactly opposite the crank throw, so that if the graduated disc is once set exactly on the timing disc hub, this setting is good for all engines. Attach the reading pointer which goes with the timing disc assembly to the two front studs of cylinder flange 1.

Set the disc to 10 degrees before top center and slowly turn the idler shaft anticlockwise, by means of the oil-pump coupling, until the intake valve starts to open, Fig. 9. This is easily checked by inserting a 0.0015-inch feeler between the valve stem and the rocker-arm roller. As soon as the feeler begins to stick, place the idler shaft gear on the hub, and attach it with three capscrews where the holes in the gear match those in the hub. Neither the idler shaft nor the auxiliaries drive shaft should be turned when this is done.

Next, check the timing of all four cam lobes to the following values, using a 0.027-inch feeler.

Intake opens—10 degrees before top center.

Intake closes—60 degrees after bottom center.

Exhaust opens—60 degrees before bottom center.

Exhaust closes—10 degrees after top center.

Each two full turns of the crankshaft brings the next cam lobe in contact with the valve gear. If in checking it is found that the timing does not correspond to the above figures, check the tappet clearance, which must

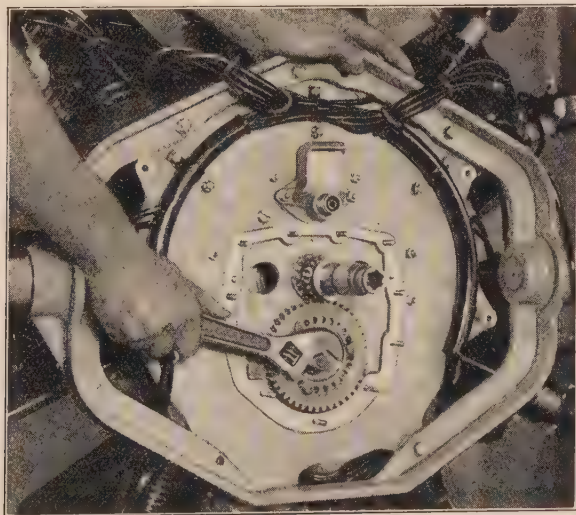


FIG. 9.

be exactly 0.027 inch. If the trouble is not in the tappet clearances, remove the three capscrows holding the timing gear to the hub, and attach the gear to the hub in such a way that the intake valve closes as nearly as possible to 60 degrees after bottom center. It will then be found that all the other timing values will be within 3 degrees of the values given in the table, this slight variation being due to the limits in machining. Do not forget to lock wire the capscrows after the timing is finished, and to set all tappet clearances to 0.010 inch, while the engine is cold. This will result in a tappet clearance of approximately 0.027 inch when the engine is warm.

Gearcase.—If, for any reason, the oil pump has been removed, assemble it to the gearcase with a new cork and a Vellumoid gasket, the studded flange toward the right-hand side. Inspect to see whether the pump gears are turning freely. Assemble the gearcase and gasket to the induction housing by fitting the oil-pump shaft over the coupling in the idler shaft. After the gearcase has been attached, turn the crankshaft and see that the pump gears are moving.

Assemble the oil strainer, the gaskets, and the relief valve, to the gearcase, seeing that the seat on the valve and in the case, is clean and smooth. Attach the magneto drives and gaskets to the gearcase. All gears should have 0.004 to 0.008 inch backlash when cold. Turn the crankshaft to make sure that the magneto drives turn freely.

Magnetos.—Attach and time the magnetos according to instructions given in the Magneto section of this book. In addition, the following must be observed:

After having set each magneto to fire as nearly as possible to 32 degrees before top center when fully advanced, by means of the adjustment provided for this purpose on the magneto coupling, slight variations between the breaking of the two magnetos must be eliminated by means of the magneto control rod. Both magnetos should break at the same instant, and this can be determined by using a feeler gage 0.0015 inch thick on each magneto. Lock the control rod and the breaker covers of the magnetos, after adjustment has been made.

Grease the rocker arms and put on all rocker-arm covers. All spark plug gaps are next checked to 0.021 inch and the plugs are screwed into the cylinder heads. It is important that the plugs be screwed in freely by hand before being tightened with the spark-plug wrench.

Attach the two cable tubes to the engine. If wires have been removed from the tube for replacement purposes, push the cables for cylinders 4 and 5 through the bottom end of the nearest tube and the cables for cylinders 3 and 6 through the small holes on the side of the nearest tube. All cables going from the left magneto to the right side of the engine and vice versa should be pulled through the clamp near the top attaching lug. Two rubber rings should be used on the cables between each magneto and the cable tubes. From the right-hand magneto the cables are connected to all rear spark plugs, and from the left-hand magneto to the front plugs. Each magneto must be wired according to the firing order, which is 1-3-5-7-2-4-6. A clip is fastened to each cylinder head for the cable leading to the front spark plug. All cables should be held to the push-rod tubes by means of rubber rings. The wiring must be checked for correct connections by following up each cable, or by a ringing-in outfit, if one is available. Remove the timing disc and the pointer.

The engine is now ready for mounting in the plane. The long oil line and the exhaust pipes must be assembled after mounting. If an engine is stored after an overhaul, or if an engine in service is laid up for any length of time, oil generously all metal parts which do not have a protective coating, in order to prevent corrosion.

TABLE OF FITS

T = tight fit. *L* = loose fit. All dimensions are in inches.

Bushings (press fit):		Minimum	Maximum
Cam-drive idler-shaft bushing in induction housing—diameter.....	0.002	<i>T</i>	0.005 <i>T</i>
Cam and magneto-drive shaft front bushing in induction housing—diameter.....	0.002	<i>T</i>	0.005 <i>T</i>
Cam and magneto-drive shaft rear bushing in gearcase—diameter.....	0.002	<i>T</i>	0.005 <i>T</i>
Piston-pin bushing in connecting rods—diameter..	0.002	<i>T</i>	0.004 <i>T</i>
¹ Rocker-arm bushing in rocker arm—diameter....	0.002	<i>T</i>	0.004 <i>T</i>
Tachometer drive shaft bushing in induction housing—diameter.	0.001	<i>T</i>	0.003 <i>T</i>
Wristpin bushing in master connecting rod—diameter.....	0.002	<i>T</i>	0.004 <i>T</i>
Valve guides (int. and exh.) in cylinder head—diameter.....	0.0012	<i>T</i>	0.0028 <i>T</i>
Ball bearings.	Tightest	Loosest	Desired fit
Crankshaft front and rear ball bearings on crankshaft—diameter.....	0.0006 <i>T</i>	0.0004 <i>L</i>	0.0001 <i>L</i>
Crankshaft front and rear ball bearings in crankcase—diameter....	0.0003 <i>L</i>	0.0021 <i>L</i>	0.001 <i>L</i>
Crankshaft thrust bearing on crankshaft spacer—diameter.....	0.0007 <i>T</i>	0.0004 <i>L</i>	0.0001 <i>L</i>
Crankshaft thrust bearing in crankcase—diameter.....	0.0003 <i>L</i>	0.0021 <i>L</i>	0.001 <i>L</i>
Crankshaft thrust bearing in crankcase—end.....	0.003 <i>L</i>	0.019 <i>L</i>	0.010 <i>L</i>
Magneto-drive shaft ball bearings on shaft—diameter.....	0.0003 <i>T</i>	0.0006 <i>L</i>	0.0001 <i>L</i>
Magneto-drive shaft ball bearings in housing—diameter.....	0.0003 <i>T</i>	0.0012 <i>L</i>	0.0002 <i>L</i>

¹ On 1928 series *scarab* only.

TABLE OF FITS.—(Continued)

Ball bearings:	Tightest	Loosest	Desired fit
Rocker-arm ball bearings on rocker shaft—diameter.....	0.0003 <i>T</i>	0.0006 <i>L</i>	0.0001 <i>L</i>
Rocker-arm ball bearings in rocker arm—diameter.....	0.0004 <i>T</i>	0.0011 <i>L</i>	0.0001 <i>L</i>
		Max. allowed clearance	
	Minimum clearance	due to wear	Desired clearance
Camfollower in guide—diameter.....	0.0005 <i>L</i>	0.002 <i>L</i>	0.001 <i>L</i>
Camfollower guide in crankcase—diameter.....	0.001 <i>L</i>	0.003 <i>L</i>	0.002 <i>L</i>
Camfollower roller on sleeve—diameter..	0.0005 <i>L</i>	0.006 <i>L</i>	0.001 <i>L</i>
Camfollower roller in camfollower—end..	0.0004 <i>L</i>	0.010 <i>L</i>	0.006 <i>L</i>
Cam-drive idler shaft in bushing—diameter.....	0.0005 <i>L</i>	0.004 <i>L</i>	0.002 <i>L</i>
Cam-drive idler shaft in bushing—end clearance.....	0.007 <i>L</i>	0.012 <i>L</i>	0.007 <i>L</i>
Cam and magneto drive shaft in bushings—diameter.....	0.001 <i>L</i>	0.0045 <i>L</i>	0.0025 <i>L</i>
Cam and magneto drive shaft in bushings—end.....	0.007 <i>L</i>	0.012 <i>L</i>	0.007 <i>L</i>
Cam ring on bearing sleeve—diameter..	0.0035 <i>L</i>	0.006 <i>L</i>	0.0045 <i>L</i>
Cam ring on bearing sleeve—end.....	0.002 <i>L</i>	0.016 <i>L</i>	0.008 <i>L</i>
Connecting rod (master) on crankshaft—diameter.....	0.0012 <i>L</i>	0.0035 <i>L</i>	0.002 <i>L</i>
Connecting rod (master) on crankshaft—end.....	0.006 <i>L</i>	0.013 <i>L</i>	0.008 <i>L</i>
Connecting rod (short) in master rod—end.....	0.005 <i>L</i>	0.012 <i>L</i>	0.007 <i>L</i>
Gears (all)—backlash (when cold).....	0.006	0.012	0.006
Piston—top diameter in cylinder.....	0.034 <i>L</i>	0.040 <i>L</i>	0.036 <i>L</i>
Piston—skirt bottom diameter in cylinder	0.013 <i>L</i>	0.020 <i>L</i>	0.015 <i>L</i>
Piston pin in piston—diameter.....	0.000	0.0015 <i>L</i>	0.0005 <i>L</i>
Piston pin in connecting rod—diameter..	0.0005 <i>L</i>	0.0025 <i>L</i>	0.0017 <i>L</i>
Piston ring (compression) in piston—side	0.002	0.0035 <i>L</i>	0.0025 <i>L</i>
Piston ring (compression) in place—gap..	0.006	0.020	0.010
Piston ring (oil regulating) in piston—side	0.001 <i>L</i>	0.003 <i>L</i>	0.002 <i>L</i>

TABLE OF FITS.—(Continued)

	Minimum clearance	Max. allowed clearance due to wear	Desired clearance
Piston ring (oil regulating) in place—gap .	0.015	0.028	0.020
Pump drive shaft in oil pump—diameter .	0.0005 <i>L</i>	0.002 <i>L</i>	0.001 <i>L</i>
Pump drive shaft in oil pump—end	0.000	0.019 <i>L</i>	0.010 <i>L</i>
Pump gears in oil pump—end	0.001 <i>L</i>	0.005 <i>L</i>	0.0025 <i>L</i>
Pump idler shaft in gears—diameter	0.0005 <i>L</i>	0.002 <i>L</i>	0.001 <i>I</i>
¹ Rocker-arm bushing on bearing sleeve— diameter	0.0015 <i>L</i>	0.008 <i>L</i>	0.002 <i>L</i>
¹ Rocker-arm bushing and thrust washer —side	0.003 <i>L</i>	0.018 <i>L</i>	0.004 <i>L</i>
Rocker-arm roller on roller sleeve— diameter	0.0005 <i>L</i>	0.006 <i>L</i>	0.001 <i>L</i>
Rocker-arm roller in rocker arm—end . . .	0.004 <i>L</i>	0.010 <i>L</i>	0.006 <i>L</i>
Tachometer drive shaft in bushing— diameter	0.0005 <i>L</i>	0.0025 <i>L</i>	0.001 <i>L</i>
Tachometer drive shaft in bushing—end .	0.007 <i>L</i>	0.012 <i>L</i>	0.007 <i>L</i>
Valve (exhaust) in valve guide—diameter	0.004 <i>L</i>	0.012 <i>L</i>	0.0045 <i>L</i>
Valve (intake) in valve guide—diameter .	0.002 <i>L</i>	0.008 <i>L</i>	0.003 <i>L</i>
Wristpin in bushing—diameter	0.0001 <i>L</i>	0.002 <i>L</i>	0.001 <i>L</i>
Wristpin in link rod			Snug fit

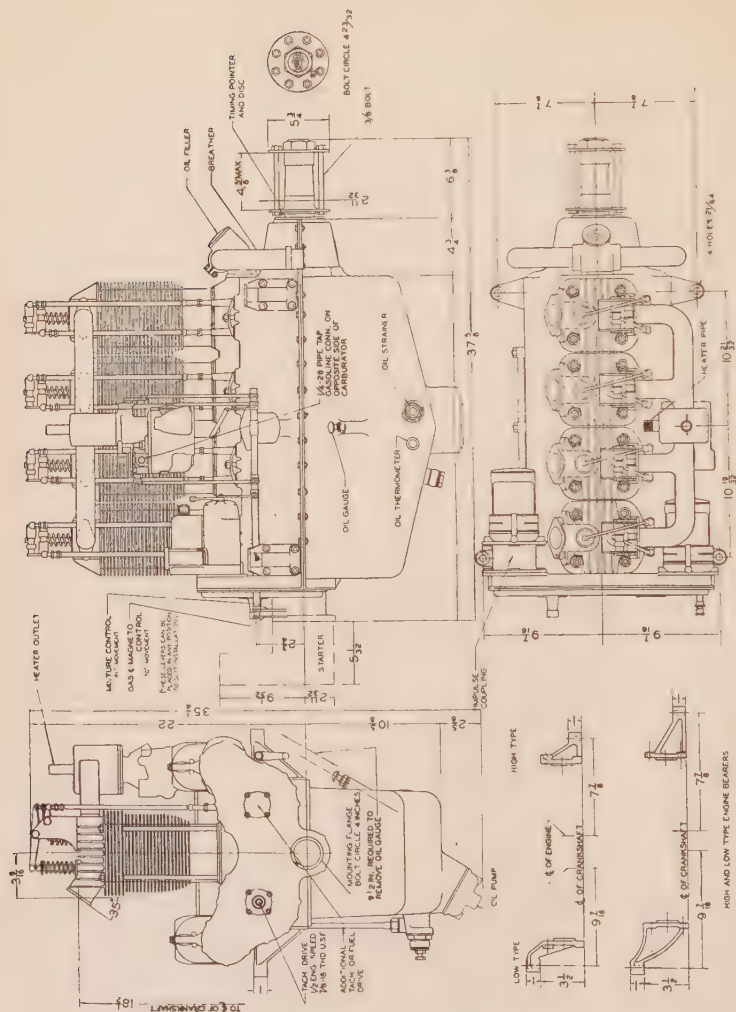
¹ On 1928 Series Scarab only.

CHAPTER 9

FOUR-CYLINDER AIR-COOLED ENGINES

Two small, four-cylinder engines, air cooled and with cylinders in line, have made their appearance, both from English designs, and both being now manufactured in this country. Both engines are similar in many ways. The Cirrus, Mark III, is shown in Fig. 1. Its main dimensions are:

Bore	4 $\frac{3}{8}$ inches
Stroke	5 $\frac{1}{8}$ inches
Displacement piston, total	310 cubic inches
Compression ratio (high compression) . .	5.4 to 1



Compression ratio (low compression)...	5.1 to 1
Normal brake horsepower.....	88 at 1,900 r.p.m. high comp.
Maximum brake horsepower.....	95 at 2,100 r.p.m. " "
Normal brake horsepower.....	86 at 1,900 r.p.m. low "
Maximum brake horsepower.....	93 at 2,100 r.p.m. " "
Weight dry.....	280 pounds
Fuel consumption.....	0.54 pounds per brake horsepower hour
Oil consumption.....	0.0213 pound per brake horse- power hour
Direction of rotation.....	Clockwise
Ignition.....	Two magnetos
Tachometer.....	One-half engine speed
Length overall.....	46.5 inches
Height overall.....	37 inches
Width overall.....	17 inches
Bearer centers.....	Front 15½ inches Rear 19 inches

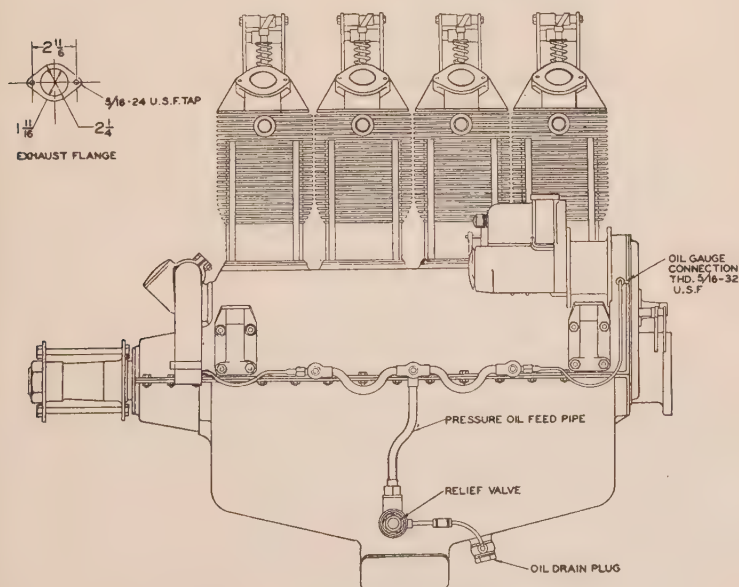


FIG. 2.—Method of lubrication.

Cylinders are of cast iron with aluminum heads which are bolted in place with copper gasket joints, and are easily removable without taking the engine down. Valve seats are of bronze, screwed into the head and expanded into place. The valve guides are of phosphor bronze and are a force fit in the crankcase. Bronze bushings are provided for the two spark plugs in each cylinder. Valve rocker arms are carried on a steel bracket bolted to top of cylinder heads.

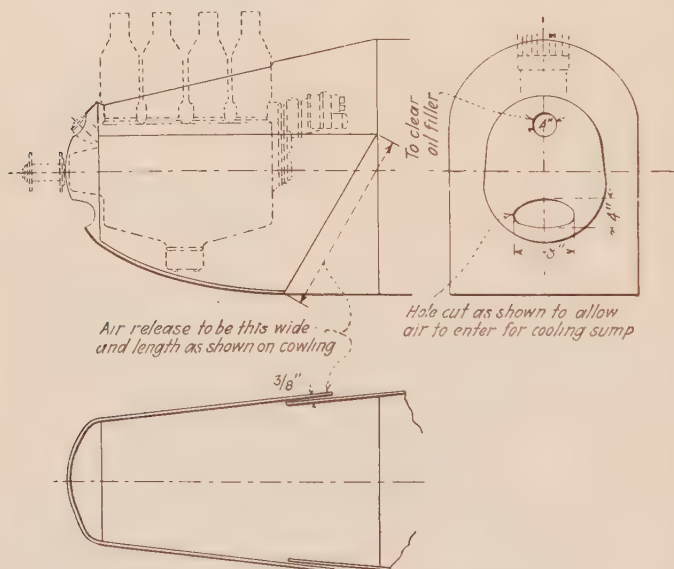


FIG. 3.—Cowling for cooling engine.

Pistons are of aluminum alloy with three cast-iron rings and a full-floating piston pin. Connecting rods are of duralumin, forged in H section, bronze-backed babbitt bearings being used on the crankpin. The four-throw crankshaft has five bearings. The three inner bearings are babbitt, while the end bearings are rollers. The lower half of the crankcase holds sufficient oil for a 5-hour flight, a geared pump forcing the oil to the bearings.

Special attention should be given to the cowling so as to direct the flow of air properly around each cylinder. Directions for this are given

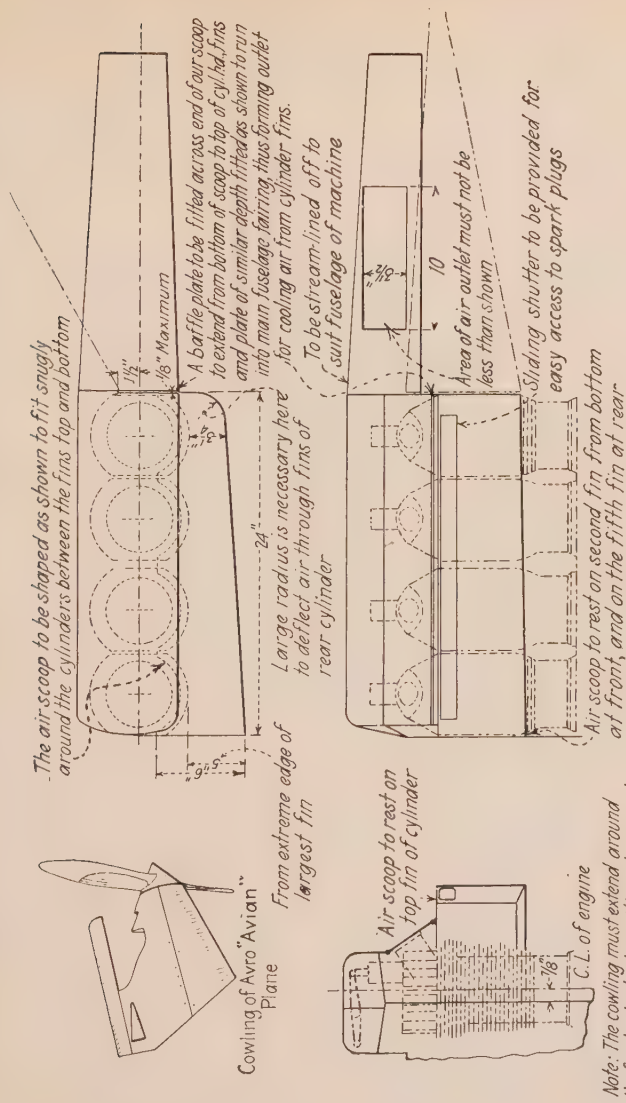


FIG. 4.—More details of cowling for other mountings.

by the makers in the accompanying diagrams. Figure 2 shows the method used in cooling the oil sump in the crankcase while Figs. 3 and 4 give details of the way in which the cowling is made to deflect the air around the cylinders so as to secure proper cooling at all times. It is important that the cowling be kept in good condition as dents or displacement may easily affect the cooling of the engine and, consequently, its reliability in service.

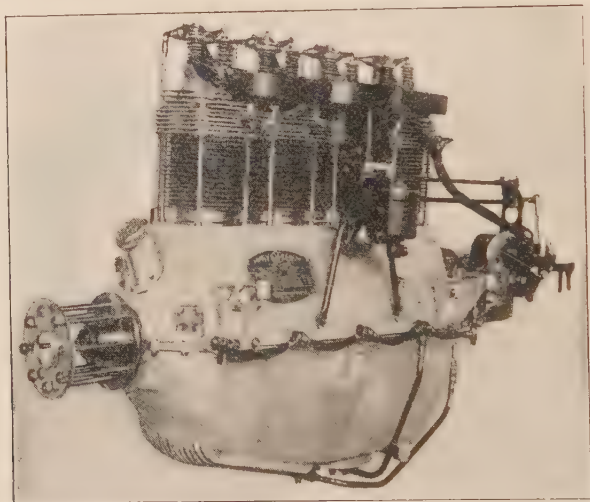


FIG. 5.—Gipsy engine showing oil piping.

These illustrations also show the method of mounting this type of engine in the fuselage and also give the main dimensions. These will be found useful in planning for this type of engine as well as in actually mounting it in a plane.

The Gipsy engine, now being built by the Wright Aeronautical Corporation, is very similar in many ways, as can be seen in Fig. 5. The main dimensions follow:

- Rotation—Left-hand tractor.
- Bore— $4\frac{1}{2}$ inches approximately.
- Stroke— $5\frac{1}{16}$ inches approximately.
- Displacement—319 cubic inches.

Normal brake horsepower—90 horsepower at 1,900 r.p.m. (Rated horsepower 85 at 1,900 r.p.m.).

Maximum brake horsepower—100 horsepower at 2,100 r.p.m. (Approximately).

Compression Ratio—5:1.

Weight—Engine complete with propeller hub, etc., 285 pounds.

Fuel Consumption—0.59 pints per brake horsepower per hour.

Oil Consumption— $\frac{1}{2}$ to $\frac{3}{4}$ pints per hour.

Similar suggestions regarding cowling apply to this engine and it is to be noted that both are so nearly like the average automobile engine of today that no one who understands motors should have any difficulty in keeping these engines in good running order.

There are also a few American engines of similar design but none of these have as yet seen the service of either the Cirrus or the Gypsy.

CHAPTER 10

CURTISS OX-ENGINE

Although the Curtiss OX-engines are no longer built, there are so many of these engines still in use that the following suggestions, authorized by the Curtiss Aeroplane and Motor Corporation will still be found useful.

The last series of OX engine was the OX-6, but they are all practically identical, with the exception of a few structural changes. The dimensions listed are for the latest model shown in Fig. 1. The OX engines have 4- by 5-inch cylinders normally run at 1,400 r.p.m., and weigh 390 pounds complete. The installation dimensions are as follows:

Overall, length, inches.....	55 $\frac{3}{8}$
Overall, width, inches.....	29 $\frac{3}{4}$
Overall, depth, inches.....	31 $\frac{1}{2}$
Width at bed (inside supports), inches.....	10 $\frac{7}{8}$
Height from bed to top, inches.....	17 $\frac{3}{4}$
Depth from bed to bottom, inches.....	13 $\frac{3}{4}$
Bed bolts (center to center), inches.....	12 $\frac{5}{32}$

The general construction of the engine can be seen from Fig. 2, while Fig. 3 shows the end view with location of the carbureters, exhaust

manifolds and water pump. Fig. 4 shows the crankcase with the studs that hold the cylinders in place.

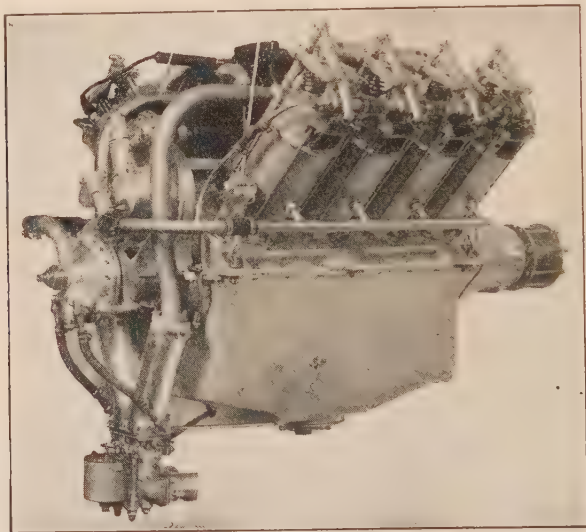


FIG. 1.—Curtiss model OX-6 engine.

SETTING UP

Study carefully the dimensions shown in the installation diagram.

The bearers or beds should be 2 inches wide by 3 inches deep, preferably of laminated hardwood, and placed $10\frac{7}{8}$ inches apart. They must be well braced.

The six arms of the base of the motor are drilled for $\frac{3}{8}$ -inch bolts, and none but this size should be used.

1. Anchoring Engine.—Put the bolts in from the bottom, with a large washer under the head of each so that the head cannot cut into the wood. On every bolt, use a castellated nut and a cotter pin, or an ordinary nut and a lock washer, so that the bolt will not work loose. Always set the motor in place and fasten before the attaching any auxiliary apparatus, such as the carbureter, etc.

2. Inspecting Ignition-switch Wires.—The wires leading from the ignition switch must be properly connected—one end to the motor body

for ground, and the other end to the post on the breaker box of the magneto (see the wiring diagram).

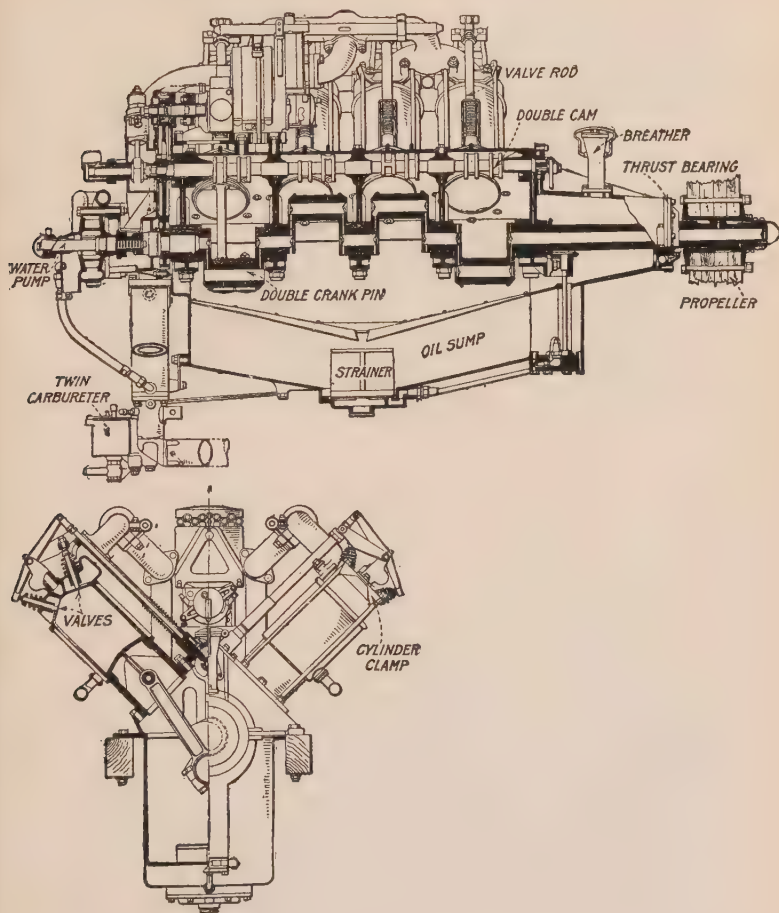


FIG. 2.—Section view of Curtiss engine.

3. Filling Radiator.—Be sure that the water from the radiator fills the cylinder jackets. Pockets of air may remain in the cylinder jackets even though the radiator may appear full. Turn the engine over a few

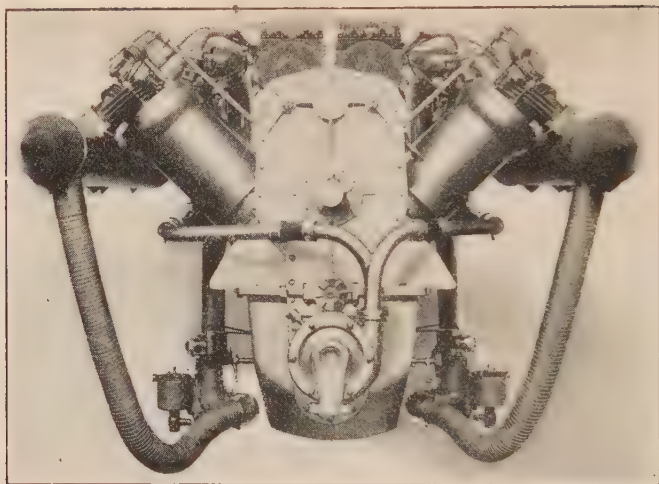


FIG. 3.—End view of Curtiss engine.

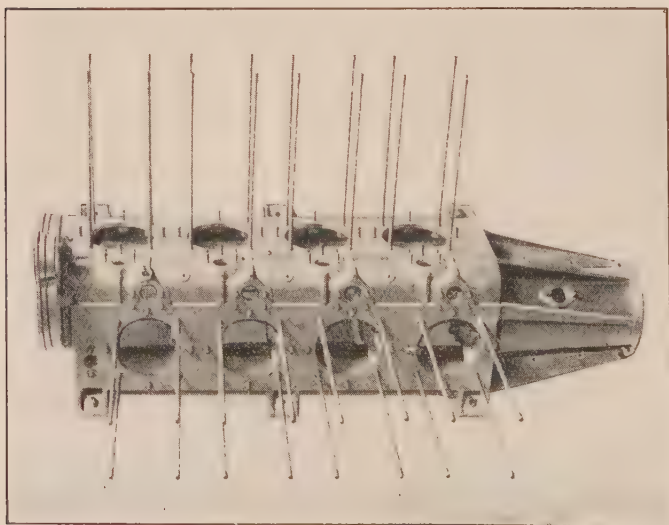


FIG. 4.—Engine base with studs.

times by hand after filling the radiator and then add more water if the radiator will take it. The air pockets, if allowed to remain, may cause overheating and develop serious trouble when the engine is running.

4. Filling Oil Reservoir.—Oil is admitted into the crankcase through the breather tube at the rear. It is well to strain all oil put into the crankcase. In filling the oil reservoir, be sure to turn the handle on the oil sight-gage till it is at right angles with the gage. The oil sight-gage is on the side of the lower half of the crankcase. Put in about 3 gallons of the best obtainable oil, Mobile A recommended. It is important to remember that the very best oil is none too good.

5. Oiling Exposed Moving Parts.—Oil all rocker-arm bearings before each flight. A little oil should be applied where the push rods pass through the stirrup straps.

6. Filling Gasoline Tanks.—Be certain that all connections in the gasoline system are tight.

7. Turning On Gasoline.—Open the cock leading from the gasoline tank to the carbureter.

8. Charging Cylinders.—With the ignition switch, prime the engine by squirting a little gasoline in each exhaust port and then turn the propeller backward two revolutions. Never open the exhaust valve by operating the rocker arm by hand, as the push rod is likely to come out of its socket in the camfollower and bend the rocker arm when the engine turns over.

9. Starting Engine by Hand.—Always retard the spark part way, to prevent backfiring, by pulling forward the wire attached to the breaker box. Failure to so retard the spark in starting may result in serious injury to the operator. Turn on the ignition switch with the throttle partly open; give a quick, strong pull down and outward on the starting crank or propeller. As soon as the motor is started, advance the spark by releasing the retard wire.

10. Oil Circulation.—Let the engine run at low speed for a few minutes, in order to establish oil circulation in all bearings.

With all parts functioning properly, the throttle may be opened gradually for warming up before flight.

VALVE SETTING AND TIMING—MAGNETO TIMING

When the motor leaves the factory, its valves are properly set and timed. Scarcely any trouble is experienced with the valves of the Curtiss engine. Under normal conditions, they are practically free from warping and pitting. As occasional grinding is necessary to bring them to a perfect seat and to clean off any collection of carbon. The inlet valves are of high-grade nickel steel; the exhaust valves are of tungsten steel.

1. Valve Setting.—After grinding and cleaning, set the inlet valves at 0.010 clearance and the exhaust valves at 0.010 clearance. This setting should be done on each cylinder just after the inlet valve has closed. If the stem is indented, due to any cause, remove the valve and grind the stem end to a flat surface.

2. Valve Timing.—After setting the clearance, turn the engine in the direction of rotation till the piston of cylinder 1 is on top dead center. Then turn the camshaft in its direction of rotation till the exhaust valve

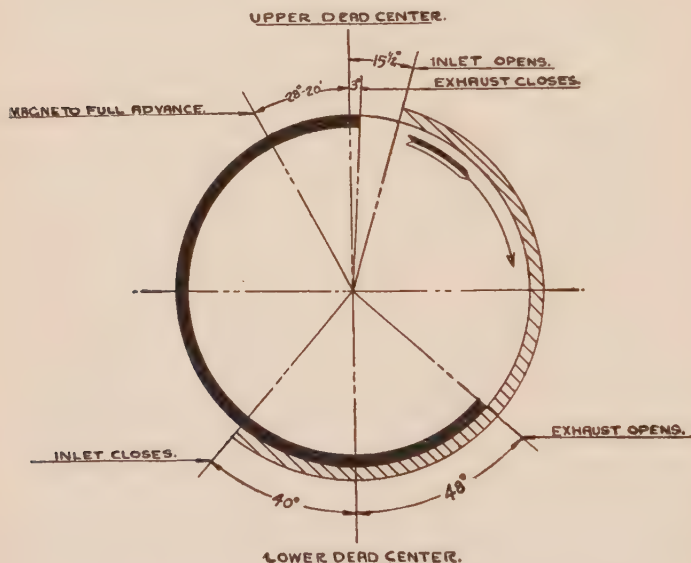


FIG. 5.—Valve-timing diagram for Curtiss OX-6.

on cylinder 1 has just closed. Put on the camshaft gear, being sure that the keyway of the gear lines up with the key in the camshaft.

Thus set and timed, the inlet valves will open $15\frac{1}{2}$ degrees past top center and close 40 degrees past bottom center; the exhaust valves will open 48 degrees before bottom center and close 3 degrees past top center as in Fig. 5.

3. Magneto Timing.—Turn the engine in the direction of rotation till the intake valve of cylinder 1 has closed; then turn the engine in the same direction till the piston of cylinder 1 is on top dead center; then turn the

motor backward till the piston of cylinder 1 is $\frac{3}{8}$ inch from top center. Turn the armature of the magneto in the direction of its rotation (it is the same as that of the crankshaft) till the distributor brush is on segment 1 with the breaker points just ready to open. Put on the magneto gear, using the same precaution as given for engaging the camshaft gear. This should bring the firing time of all cylinders to 28 degrees before top center. The distributor diagram is shown in Fig. 6.

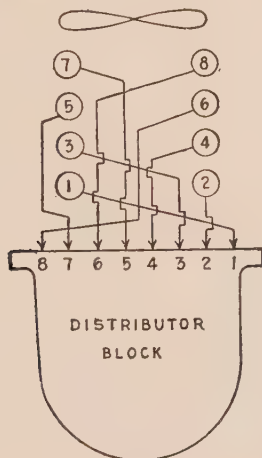


FIG. 6.—Distributor block.

The spark advance lever should be in the position of full advance during this whole operation. The gap between the breaker points should be 0.018 inch, and that of the spark-plug points, 0.023 inch.

IGNITION

The magneto used on the Curtiss engine is of the high-tension type. The firing order and cylinder arrangement are as shown on the wiring diagram.

Ignition troubles are usually traced to faulty spark plugs. A common cause of spark-plug failure lies in the intensity of the spark itself, the latter eventually burning away the electrodes and thereby widening the gap, which, at low speed, causes missing. To test a spark plug, connect it up with its terminal and lay it upon a cylinder of motor for ground connection.

Turn the engine over briskly, and the spark plug should give a good spark.

All gasoline connections should be cut off before this test.

Trouble with the magneto itself is sometimes due to dirt and overlubrication. If the magneto is suspected of being at fault, unscrew one of the spark plugs, connect it up with its terminal, and lay it upon a cylinder of the motor for ground connection. Crank the engine vigorously. If no spark is seen, it will be the wiser course to unscrew several plugs and subject them to the same test before condemning the magneto or the wiring. Should no spark appear as the several plugs are tested, detach the switch wire from the magneto terminal on the interrupter housing cover and test the plugs again. A spark under these conditions will indicate a short circuit in either the switch or the switch cable. If there is no spark, the interrupter should be inspected—care being taken to see that the platinum points are clean and smooth and that the interrupter lever moves freely on its pivot. If the spark still fails, remove the aluminum bonnet from the shaft end of the magneto, thus exposing the safety spark gap. Turn the engine over rapidly. If a spark is seen in the safety spark gap, the fault will be found not in the magneto but in the distributor, in the spark-plug cables, or in the spark plugs themselves. If no spark is visible in the safety spark gap, the trouble is internal; the magneto must be returned to the manufacturer for repairs. Under no conditions should the magneto be taken apart beyond the removal of the interrupter, the distributor plate, and the bonnet from the shaft end. Nothing good can be accomplished by removing the end plates of the magneto, and permanent injury is almost sure to result.

The inside of the commutator should be kept clean and lubricated with high-grade cylinder oil—not in too large quantities, however. Graphite should never be used on the commutator.

Lift out the distributor plate occasionally, without disarranging the wiring, and remove any accumulation of oil, dirt, or moisture.

LUBRICATION

The proper lubrication of any mechanism is of so vital importance and any neglect is so sure to cause expensive repairs that the mechanician should make it his unfailing habit to look after it daily. The Curtiss lubrication system is easily understood and requires little time for proper attention.

The system is force feed and spray.

The lower half of the crankcase is used as the oil reservoir and carries a sight-gage that indicates at all times the quantity of oil it contains. The

case is so designed that its center is always its lowest point and is consequently the point at which the oil always gathers. This is a highly important feature of Curtiss construction, as at no practical flying angle can the cylinders become flooded with oil. Inside the crankcase are two baffle plates sloping from the ends toward the center and leaving at the bottom a $\frac{3}{4}$ -inch opening their full width.

A simple gear pump forces the oil from the low point of the crankcase sump; through the hollow camshaft to all the camshaft bearings; thence through connecting tubes to the crankshaft bearings. From these bearings the oil passes through the holes drilled in the crankshaft into the hollow crankshaft, and the hollow crankshaft throws to the connecting-rod bearings.

The oil is thrown off the crankpin bearings in a spray, on to the piston pin bosses, thence through holes in bosses to piston-pin bearings. Grooves in the pistons carry the oil up on to the cylinder wall.

The magneto gear and camshaft gear are lubricated by spray from a hole in the retaining screw of the camshaft gear. The thrust bearing is lubricated by spray from a hole in the rear of the crankshaft.

The oil pressure is regulated by a regulating valve in the line, which acts as a bypass allowing the surplus oil to flow into the oil sump.

All bearing pins for the rocker arms and for the forked ends of the push rods are hollow but plugged at both ends. Minute holes are drilled in alignment with the external holes. As oil is forced into these external holes the hollow spaces inside the pins act as reservoirs and will oil evenly all bearings of the rocker-arm mechanism for several hours after being filled.

OVERHAULING AND INSPECTION

Every engine should have a complete inspection at the end of every 50 running hours. To do this properly, the engine must be dismantled. When new, the engine should not be run for more than 5 hours, without thoroughly draining off all oil and carefully cleaning the strainer. This procedure should be repeated at the end of the second 5-hour period of operation, and then at the end of the next 10-hour period.

Any first-class engine mechanic can do this work, noting these few points carefully.

The crankshaft and crankpin bearings are made 0.002 to 0.003 inch larger than the journal. The bearings should **never** be tighter than this, and a trifle more clearance will do no damage. Scraping the bearings should be undertaken only when absolutely necessary, as when relining or when one is cut or burned from dirt or insufficient lubrication.

Clean carbon from the ^{*}pistons and cylinders and free any rings that may be stuck in the groove. Lap all valves that leak, being careful to leave no ridges on either valve or seat. Clean and oil carefully all parts when reassembling.

CARBURETION

If adjustment of carbureter is found necessary, it should be attempted only by one thoroughly competent and strictly according to the instruction pamphlet issued by the maker of the carbureter.

IMPORTANT DON'T'S

1. Don't forget that "a stitch in time saves nine."
2. Don't forget to inspect the motor thoroughly before starting.
3. Don't try to start without oil, water, or gasoline; all three are vital.
4. Don't forget to see that the radiator is full of water.
5. Don't get dirt or water into the oil.
6. Don't get dirt or water into the gasoline.
7. Don't forget to oil all exposed working parts.
8. Don't try to start without retarding the magneto; a serious accident may result.
9. Don't try to start without turning on the switch.
10. Don't start the motor with throttle wide open.
11. Don't run the motor idle too long; it is not only wasteful but harmful.
12. Don't forget to watch the lubrication; it is most essential.
13. Don't forget that the propeller is the business end of the motor; treat it with profound respect—especially when it is in motion.
14. Don't cut off the ignition suddenly when the motor is hot; allow it to idle for a few minutes at low speed before turning off the switch. This insures the forced circulation of the water till the cylinder walls have cooled considerably and also allows the valves to cool, preventing possible warping.
15. Don't fail to study the trouble charts that follow before you molest a thing about the motor, if you have trouble.
16. Don't develop that destructive disease known as tinkercitis; when the motor is working all right, let it alone.
17. Don't forget a daily inspection of all bolts and nuts. Keep them well tightened.
18. Don't fail to stop your motor instantly upon detecting a knock, a grind, or any other noise foreign to perfect operation. It may mean the difference between saving or ruining the motor.
19. Don't fail to study these instructions thoroughly. Figures 2, 3 and 4 show construction of motor.

THE TROUBLE CHART

This chart has been prepared to outline in a simple manner the various troubles that interfere with the efficient action of aeronautical motors.

The various defects that may develop are tabulated in a manner that makes for ready reference, and opposite the part affected the various conditions are found under a heading that denotes the main trouble to which the others are contributing causes.

The various symptoms denoting the individual troubles outlined are given to facilitate their recognition in a positive manner. Brief note is also made of the remedies for the restoration of the defective part or condition.

It is apparent that a chart of this kind is intended merely as a guide, and it is a compilation of practically all the known troubles that may materialize in gas-engine operation. While most of the defects outlined are common enough to warrant suspicion, all will never exist in an engine at the same time; and it will be necessary to make a systematic search for such of those as do exist and by the process of elimination, locate the offending part.

To use the chart advantageously, it is necessary to know and recognize easily one main trouble. For example, if the motor is skipping, look for possible troubles under the heading Skipping. If the motor fails to develop power, the trouble will undoubtedly be found under Lost Power and Overheating.

It is assumed in all cases that the trouble exists in the power plant or its components and not in the auxiliary members of the ignition. In many instances, however, the seat of trouble will be traced to these latter members.

LOST POWER AND OVERHEATING

Part at fault	Trouble	Effect	Remedy
24 Manifold connections	Poor mixture in one set of cylinders with good mixture in other set	Surging or pulsating	Tighten connections; put in new gaskets
25 Water-pipe joint	Loose Defective gasket	Loss of water and overheating	Tighten bolts or replace with new connection
26 Spark plug	Loose in threads Defective gasket	Poor compression and overheating	(See No. 1) Screw down tight Replace with new
27 Combustion chamber	Crack or blowhole Roughness Carbon deposit	Poor compression Pre-ignition Pre-ignition	Fill by welding or replace with new Smooth up Remove carbon
28 Valve-head	Warped, scored, or pitted Carbonized or covered with scale	Poor compression	True up in lathe and grind to seat Scrape off smooth with emery cloth
29 Valve seat	Warped or pitted Carbonized or covered with scale	Poor compression or blowback	Use reseal reamer Clean off and grind to seat
30 Piston rings	Loss of spring Loose in groove Worn or broken Slots in line	Poor suction, leak of gas, and overheating Poor compression	Peen rings or replace with new Loosen rings on piston
31 Piston rings	Broken because too tight Insufficient opening	Scored cylinder walls, overheating in sump pan, and poor compression	Replace scored cylinder if groove is deep; use new rings
32 Wristpin	Loose Scored cylinder	Poor compression	Fasten securely Replace scored cylinder if groove is deep
33 Piston head	Carbon deposit Crack or blowhole (rare)	Pre-ignition Poor compression	Remove carbon Replace with new
34 Piston	Binds in cylinder Walls scored or worn out of round	Overheating	Lap off excess metal Replace with new

LOST POWER AND OVERHEATING.—(Continued)

Part at fault	Trouble	Effect	Remedy
35 Cylinder wall	Scored Poor lubrication causes friction	Poor compression and overheating	Replace with new Lap in cylinder Repair oiling system
36 Camshaft Drive gear	Loose on shaft Not properly meshed Worn or broken teeth	Irregular valve action	Fasten to shaft Time properly Replace with new
37 Crankshaft	Scored or rough on journals Sprung	Overheating Overheating	Smooth up Straighten
38 Crankpin Bearings and main bearings	Adjusted too tight Defective oiling	Overheating	Adjust to running clearance Clean out oil holes
39 Oil sump	Insufficient oiling Poor oil Dirty oil	Overheating and burned-out bearings	Replenish supply Use best oil—Mobile "A" recommended Wash with kerosene Replace with new oil
40 Water space and water pipes	Clogged with sediment or scale	Overheating	Dissolve and remove foreign material
41 Radiator hose	Layer of hose obstructs opening	Overheating	Refit or replace with new
42 Water pump	Impeller loose on shaft Dirty Broken	Overheating	Fasten to shaft Clean Replace with new

LOST POWER AND OVERHEATING

Part at fault	Trouble	Effect	Remedy
24 Manifold connections	Poor mixture in one set of cylinders with good mixture in other set	Surging or pulsating	Tighten connections; put in new gaskets
25 Water-pipe joint	Loose Defective gasket	Loss of water and overheating	Tighten bolts or replace with new connection
26 Spark plug	Loose in threads Defective gasket	Poor compression and overheating	(See No. 1) Screw down tight Replace with new
27 Combustion chamber	Crack or blowhole Roughness Carbon deposit	Poor compression Pre-ignition Pre-ignition	Fill by welding or replace with new Smooth up Remove carbon
28 Valve-head	Warped, scored, or pitted Carbonized or covered with scale	Poor compression	True up in lathe and grind to seat Scrape off smooth with emery cloth
29 Valve seat	Warped or pitted Carbonized or covered with scale	Poor compression or blowback	Use reseal reamer Clean off and grind to seat
30 Piston rings	Loss of spring Loose in groove Worn or broken Slots in line	Poor suction, leak of gas, and overheating Poor compression	Peen rings or replace with new Loosen rings on piston
31 Piston rings	Broken because too tight Insufficient opening	Scored cylinder walls, overheating in sump pan, and poor compression	Replace scored cylinder if groove is deep; use new rings
32 Wristpin	Loose Scored cylinder	Poor compression	Fasten securely Replace scored cylinder if groove is deep
33 Piston head	Carbon deposit Crack or blowhole (rare)	Pre-ignition Poor compression	Remove carbon Replace with new
34 Piston	Binds in cylinder Walls scored or worn out of round	Overheating	Lap off excess metal Replace with new

LOST POWER AND OVERHEATING.—(Continued)

Part at fault	Trouble	Effect	Remedy
35 Cylinder wall	Scored Poor lubrication causes friction	Poor compression and overheating	Replace with new Lap in cylinder Repair oiling system
36 Camshaft Drive gear	Loose on shaft Not properly meshed Worn or broken teeth	Irregular valve action	Fasten to shaft Time properly Replace with new
37 Crankshaft	Scored or rough on journals Sprung	Overheating Overheating	Smooth up Straighten
38 Crankpin Bearings and main bearings	Adjusted too tight Defective oiling	Overheating	Adjust to running clearance Clean out oil holes
39 Oil sump	Insufficient oiling Poor oil Dirty oil	Overheating and burned-out bearings	Replenish supply Use best oil—Mobile "A" recommended Wash with kerosene Replace with new oil
40 Water space and water pipes	Clogged with sediment or scale	Overheating	Dissolve and remove foreign material
41 Radiator hose	Layer of hose obstructs opening	Overheating	Refit or replace with new
42 Water pump	Impeller loose on shaft Dirty Broken	Overheating	Fasten to shaft Clean Replace with new

NOISY OPERATION

Part at fault	Trouble	Effect	Remedy
43 Spark plug	Leakage	Hissing	Screw down tighter Replace with new
44 Cylinder wall	Scored	Knocking	Smooth up or replace with new
45 Manifold pipe joints	Leakage Defective gaskets	Sharp hissing	Tighten bolts Replace with new
46 Combustion chamber	Carbon deposit	Knocking	Remove carbon
47 Cylinder casting	Retaining bolts loose	Sharp metallic knock	Tighten bolts
48 Cam	Worn contour	Metallic knock	Replace with new
49 Piston head	Carbon deposit	Knock	Remove carbon
50 Wristpin	Loose in piston Worn	Dull metallic knock	Replace or bush
51 Connecting rod	Worn at wristpin or crankshaft Sideplay in piston	Distinct knock	Adjust or replace Scrape and fit and oil
52 Main crankshaft bearing	Loose Defective lubrication	Metallic knock Squeak	Fit caps close to shaft Clean out oil holes and oil
53 Connecting-rod bearings	Loose Excessive play Binding	Intermittent metallic knock Knock and squeak	Refit Reline
54 Connecting-rod bolts, main-bear- ing bolts	Loose Stripped threads	Sharp knock	Tighten Replace bolts

NOISY OPERATION.—(Continued)

Part at fault	Trouble	Effect	Remedy
55 Lower half crankcase bolts	Loose Stripped threads	Knock and rattle	Tighten New bolts
56 Water jacket	Covered with scale Clogged with dirt	Knock caused by overheating	Dissolve scale and flush out water space with water under pressure
57 Timing gears	Loose Worn or broken teeth Meshed too deeply	Metallic knock Rattle Grinding	Fasten to shaft Replace with new gear
58 Camshaft bearing	Loose or worn	Slight knock	Replace with new
59 Inlet-valve seat	Warped or pitted Dirty	Rattle Poor compression Blowback	Use reseal reamer Clean off and grind to seat
60 Inlet-valve spring	Weak or broken	Blowback in carbu- reter	Replace with new
61 Inlet valve	Closes late Opens early	Blowback in carbu- reter	Time properly
62 Valve-stem guide	Worn or loose	Rattle or click	Replace with new guide
63 Camfollower guide	Loose	Rattle or click	Replace with new guide
64 Valve-stem clearance	Too much Too little	Click Blowback in carbu- reter	Set inlet gap 0.010 Set exh. gap 0.010
65 Push-rod reten- tion stirrups	Nuts loose	Rattle Blowback in carbu- reter	Tighten nuts
66 Crankcase gaskets	Leak	Oil leak	Tighten bolts Replace with new
67 Cylinder or piston	No oil Poor oil	Grinding and sharp knock	Repair oil system Use best oil

NOISY OPERATION.—(Continued)

Part at fault	Trouble	Effect	Remedy
68 Piston	Binding in cylinder Worm oval causing side slap	Grind or dull squeak Dull hammer	Lap off excess metal Replace with new
69 Oil sump	Insufficient oil Poor oil	Grind and squeak in all bearings	Replenish with best oil
70 Piston rings	Defective oiling	Squeak, hiss, grind	Replace with new ring Repair oil system
71 Crankshaft	Defective oiling	Squeak	Clean out oil holes Use best oil Repair oil system
72 Engine base	Loose on frame	Dull pound	Tighten bolts
73 Water pipe	Leak Clogged Defective gaskets	Engine heats	Tighten connections Clean Replace with new

CHAPTER 11

THE WRIGHT-HISPANO ENGINE

This type of engine, though now out of production, is still used to some extent in commercial planes. It was manufactured in France and England, and by the Wright Aeronautical Corporation in the United States.

The "Hisso" engine, Fig. 1, as it is frequently called, is a V-type engine but has several peculiarities of design which make it different from any other. The cylinders are steel sleeves, solid at the upper end, and the valve seats are formed directly in the top of the cylinder itself. The outside of the cylinder sleeve is threaded and screws into the aluminum casting which looks like a cylinder block but is, in reality, only the water jacket for the four cylinders of the block. The lower end of the cylinder projects and has a flange by which the cylinder block is fastened to the engine base by studs.

Overhead camshafts with liberal-sized cams, act directly on the top of adjustable caps over the valve stems. Instructions for setting up and handling the engine follow:

Model I, Wright-Hispano engine is of the eight-cylinder, 90-degrees, V-type, water-cooled type. The cylinders are approximately $4\frac{3}{4}$ by $5\frac{1}{8}$ -inch bore and stroke, and develop 150 horsepower at 1,450 r.p.m. at sea level. There are two cylinder blocks, each containing four cylinders and forming the water jackets and valve ports, intake and exhaust passages.

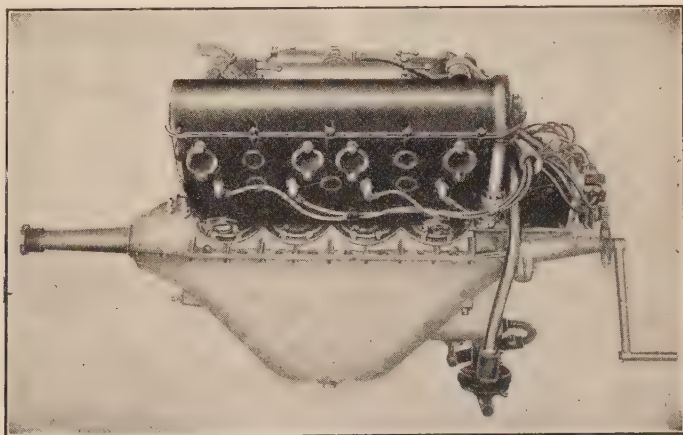


FIG. 1.—Wright-Hispano engine.

The pistons are aluminum castings, ribbed, and provided with four narrow rings at the top on two grooves and one oil ring near the bottom. The hollow, case-hardened, alloy-steel piston pins are held in the pistons by a piston-pin lock ring which acts also as a piston ring.

The connecting rods are of tubular section; the material, heat-treated alloy steel. One rod turns directly on the crankpin, while the other, which is forked, turns on the outside of the extended part of the former. The upper ends of the connecting rods are provided with bronze bushings.

The crankshaft is of chrome-nickel steel of the four-throw type, 180 degrees between throws, machined all over. There are four plain main bearings, bronze backed and babbitt lined, and one annular ball main bearing at the rear (cranking) end. The thrust for either

a tractor or propeller screw is provided for by a double-row ball thrust bearing located in the front of the crankcase. The crankshaft is provided with a conical seat with key for the propeller hub and is bored hollow for lightness and for the oiling system.

The valves are set vertically in the cylinders along the center of each block and are directly operated by a single camshaft located over the valves. They are of tungsten steel, with large-diameter, hollow stems, working in tight-fitting, cast-iron bushings, provided at the upper ends with case-hardened, flat-headed adjusting discs, upon which the cams operate and are held to their seats by two concentric helical springs each, either one of which is sufficient, in case of breakage to the other, to insure the valves seating properly.

The hollow camshafts are mounted in three plain bronze bearings each and driven from the crankshaft by two vertical shafts and bevel gears of hardened alloy steel running in plain bronze bearings. These shafts are protected by housings of light steel tubing and each one is provided with a screwdriver type of joint near the middle, allowing of ready removal of the cylinder blocks without dismounting other parts. The camshafts, cams, and heads of the valve stems are all enclosed in oil-tight, cast-aluminum, removable housings. The camshaft is driven by conical gears.

The oiling of the engine is provided for by a positive-pressure system, a sliding-vane eccentric type of pump being mounted vertically directly below the crankshaft in the lower half of the crankcase and driven by the same bevel gear that drives the camshaft drive shafts. This pump takes oil through a pipe cast integral with the lower crankcase, forces it through a filter also cast in the case and provided with a removable screen; and then through other steel tubes cast in the case to three of the main bearings. From these bearings the oil enters the hollow crankshaft and is distributed to the four crankpins, proper oil holes and grooves being provided in the inner connecting rods to distribute the oil where needed. The lubrication of the cylinders and of the piston pins is provided for by oil thrown off from the rapidly revolving crankshaft. The fourth main bearing is also provided with an oil lead from the system, which takes care of the lubrication of this bearing and, through tubes running up the end of each cylinder block, provides oil for the camshafts. As the camshafts are hollow, the oil is forced into them at one end through one of the bearings. Lubrication of

the cams is provided by a small hole in each cam and of the remaining bearings by other small holes. The excess of oil escapes through the other end of the camshaft in the form of a stream and oils the driving gears before it returns to the crankcase.

Ignition is furnished by two eight-cylinder magnetos firing two spark plugs per cylinder. One magneto is driven from each of the two vertical shafts by small bevel pinions meshing in bevel gears mounted directly on the magneto shafts.

All engines used in seaplanes or planes of the pusher type are equipped with a geared-down, hand-crank starting device and, when thus equipped, are geared up to a small starting magneto which gives a very hot spark at low engine speeds.

ADJUSTMENTS

Valve Clearances.—The clearance between the valve discs and the cams should be 2 millimeters (0.0787 inch). It is important to check this clearance from time to time and correct it if it varies, using the special wrench and the gage supplied for that purpose in the equipment.

Valve Timing.—In case it is necessary to demount the camshafts or the gears, the following is the method to use in order to determine the opening and closing positions of the valves:

1. Determine, as indicated above, the clearance between the cams and valve discs.

2. Mount on the taper of the crankshaft a disc 360 millimeters (14.1734 inches) in diameter. If this is not available, mark the timing on the propeller hub itself, which has a diameter of 180 millimeters (7.0867 inches).

3. Place between the axis of the cylinder groups an arrow which will coincide with the rim of the disc or the propeller hub.

4. On the face of the timing disc or hub flange, mark the top and bottom center, with regard to the arrow, and from these marks lay off the distances as indicated in the timing diagram (Fig. 2) so that these lines correspond exactly to the motor timing.

When the adjustment of one set is finished, the same procedure should be applied for the other, but taking account of the firing and timing which is in the following order:

1L-4R-2L-3R-4L-1R-3L-2R

For example: We know that cylinder 4R (4 right) intakes after 1L (1 left); hence, we begin again with the intake opening of 1L and by turning the crankshaft 90 degrees (one-fourth revolution) in the

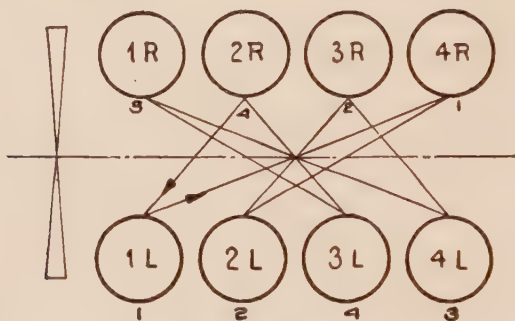


FIG. 2.—Timing diagram.

direction of rotation, we have determined the opening of intake valve of cylinder 4R.

TIMING DIAGRAM

Timing	Length of arc taken in diameters	
	Of 360 millimeters (14.1734 inches)	Of 180 millimeters (7.0867 inches) ¹
Intake opens.....	32 millimeters (1.2599 inches)	16 after top ctr.
Intake closes.....	165 millimeters (6.4962 inches)	83 after bottom "
Exhaust opens.....	150 millimeters (5.9056 inches)	75 before " "
Exhaust closes.....	32 millimeters (1.2599 inches)	16 after top "
Spark advance.....	64 millimeters (2.5197 inches)	32 before top "

¹ The diameter of the propeller flange is 180 millimeters (7.0867 inches).

TIMING OF MAGNETOS

1. Mark the points of maximum advance, as indicated on the timing diagram, on the face of the 360-millimeter (14.1734 inches) timing disc or on the propeller-hub flange.

2. Turn the crankshaft of the engine until cylinder 1L is nearing the end of the compression stroke and the spark advance line on the disc coincides with the timing arrow.

3. Turn the magneto shaft until the distributor brush touches the distributor segment, which is marked for cylinder 1L and bolt down the magneto.

4. Loosen the three small bolts which hold the magneto gear to the disc and turn the disc until the platinum points of the circuit breaker just begin to separate. (Use cigarette paper between the points for timing.) Then tighten the bolts.

The two magnetos should be timed in exactly the same manner, and if one or the other of the magnetos is cut out while the engine is running, the number of revolutions of the engine lost should be the same (about 20).

Spark-plug Connections.—The distributor diagram (Fig. 3) facilitates the connection of spark-plug wires.

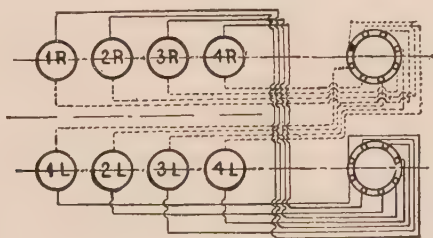


FIG. 3.—Wiring diagrams.

All spark plugs located on the intake side of the cylinders are wired to the right-hand magneto, while the plugs located on the exhaust side are wired to the left-hand magneto. If there is any misfiring, this arrangement makes it very easy to find which side has the bad spark plug.

OPERATION

Running the Engine.—Never “load” the engine immediately after starting it. Particularly in winter, allow it to operate at partly closed throttle, or about 800 r.p.m.

In very cold weather, it is advisable to stop it after 3 or 4 minutes’ operation and wait a little time until the heat communicates to all parts of the crankcase, in order to render the oil thinner.

The engine is controlled by the gas throttle and is found to start best with a very small opening. The throttle lever should be about $\frac{3}{16}$ inch from the stop screw. The second control is designed to correct the variations in carburetion required at the different altitudes where the engine is to operate.

One should determine a fixed point, before each start, of the best position for the altitude control (that which corresponds to the greatest number of revolutions). That position generally is satisfactory up to 1,000 meters (3,280 feet). Above that, it is necessary to make corrections, always, of course, determined by the revolution counter.

Starting the Engine.—It is best to prime the engine through the petcocks on the intake pipes when starting the engine cold. If the engine is warm, no priming should be used. The choke valve of the carbureter should be raised as far as possible, and with the carbureter flooded and set as before referred to for starting, the engine should then be turned over at least two complete revolutions, the choke set back in the normal position again, and it will then be ready to start off. Never prime the engine when it is warm.

LUBRICATION

Notice.—If, in starting a new engine which is being run without an oil radiator, the oil pressure does not register make sure that the end of the oil-pump suction pipe is not closed with a brass plug. This can be examined by removing the plug in the bottom of the lower half of the crankcase.

Before each start, be sure of the level of the oil in the crankcase with the aid of the gage plugs placed for this purpose in the sump.

The normal level corresponds to the height of the second plug, giving about 10 liters (2.64 gallons) in the case.

The oiling of all parts of the engine is automatic, under pressure. The magnetos need several drops of oil in the oil feed every 20 hours.

A good lubricating oil or some good grade of castor oil is recommended.

MAINTENANCE

After 5 hours' running, the distributor blocks of the magnetos should be cleaned to avoid any skipping or missing in their operation. The brushes of the high-tension distributor should be oiled, preferably

with lubricating oil; likewise, the path of the brushes in the distributor block should have a coating of oil. This prevents the scattering of carbon dust in the distributor blocks, which causes short circuiting or firing in the wrong cylinder.

After 10 hours' running and before each important flight, clean the spark plugs (with alcohol if they are greasy from castor oil), the magneto distributors, and the oil filter.

Every 20 hours clean the gasoline strainer and the water filters.

Every 50 hours clean out the combustion chambers after the cylinders have been taken off; grind the valves. Never unscrew the cylinders from the water jacket. After reassembly, be sure that the timing is correct.

PRECAUTIONS TO TAKE UNDER FREEZING CONDITIONS

The circulating water can be kept from freezing by adding 25 per cent of glycerin. Without that precaution, it is necessary to drain the water each night.

In order to facilitate starting in the morning and freeing (ungumming) the rings, it is advisable to give, while the engine is still hot, after the previous run, several shots of kerosene through the petcocks of the inlet manifolds and turn the propeller over several times.

RECOMMENDATIONS FOR ATTACHING PROPELLERS

Always put the keyway of the hub in the axis of the blades. Starting the engine by cranking the propeller is facilitated if the propeller is keyed in that position which is the most favorable for "carrying over compression." More than that, this position has been adopted for adjustment of the layout for firing the machine gun through the propeller. That recommendation, then, becomes very important.

The mounting of the hub on the taper of the crankshaft requires very particular precautions; the hub supplied with each engine has been fitted to its taper; do not omit that operation in case of replacement of the hub.

Before mounting, be sure that the parts fit perfectly and are lubricated with tallow or oil and graphite. A bad fit rapidly develops play and, if run in this condition, will do great damage.

A faulty balance of the propeller always causes vibration. As soon as one encounters this condition, correct the balance with care.

RECOMMENDATIONS FOR INSTALLING THE ENGINE IN AIRPLANES

The engine should be anchored on a rigid support which must be straight and smooth, where the engine is fastened on, and should be lined with fiber.

Housing-in of the Engine.—Whenever possible, the camshaft housing covers should be left exposed; their disassembly is then very easy, and this arrangement permits the constructor to cut down the size of the cowls. If, in certain cases, the engine is mounted without any cowls, some method of sheltering the magnetos should be provided for.

PARTS TO WHICH EASY ACCESS AND EASY TAKE-DOWN IS DESIRABLE

Magnetos—spark plugs—oil-level plugs—oil filters—crankcase breather tube cap.

Carbureter.—Air should be taken in the outside by a leakproof tube and made with a minimum inside diameter of 90 millimeters (3.5434 inches). At the lower part of the carbureter is a nipple, to which a small tube should be fastened, which lets the gasoline run off, this tube discharging far enough to the rear under the airplanes (as far away from the exhaust as possible).

In addition to the throttle valve controlling the speed of the engine, there is also installed in the pilot's cockpit another control operating the altitude-corrective mechanism of the carbureter.

There should be, also, as close to the engine as possible, a cock enabling the pilot to shut off the gasoline supply.

Water Circulation.—It is important in any case, that there be a sufficient head of water above the highest part of the cylinder water space. This head should never go below 30 centimeters (11.811 inches); when two side radiators are used, they should be joined, if possible, by a communicating tube on top. The circulating system should have at its highest point a small expansion tank with a level cock, which avoids complete refilling of the tank. The space in the tank above the level cock should not have less than 3-liter (3-quart) capacity, to allow for the expansion of the water. It is indispensable to locate, in an accessible manner, a filter between the cylinder outlets and each

radiator, to stop sediment in the water which deposits in the jackets and tends to clog the radiators.

The delivery of the water pump is in the neighborhood of 100 liters (26.41 gallons) per minute at 1,400 r.p.m. The difference between the inlet and outlet temperature of the water is about 10° C. (20° F.).

Oil Tank and Cooling of Oil.—If the engine is mounted on a machine intended to make flights of more than 3 hours, it will be necessary to install an oil reservoir, allowing 2 liters (2 quarts) of oil used per hour.

This tank may be used as an oil-cooling radiator.

In this case, the suction pipe in the pump must, of necessity, be plugged. (A brass plug, which is furnished, may be screwed into the taped end of the oil intake by removing the sump drain plug.)

Connect the bottom of the oil radiator by a pipe to one or the other of the oil plugs located in the rear of the crankcase, on the intake side of the oil pump. The return to the radiator is made by a pipe joined to the sump drain plug.

These suction and delivery oil pipes should have an inside diameter of 14 millimeters (0.5512 inch) for the suction pipe and 28 millimeters (1.1024 inches) for the return; the radiator tubes, at least a 10-millimeter (0.3937 inch) inside diameter.

It is always necessary to equip the top part of the reservoir with a plug for the release of air when refilling.

SECTION V

TROUBLE SHOOTING FOR AIRPLANE ENGINES

Preliminary Knowledge.—To be able to shoot trouble successfully and systematically it is necessary to know:

1. The general design of the motor, the magneto, and the carbureter.
2. The direction of rotation and firing order.
3. What the motor is supposed to perform—the highest r.p.m.; lowest r.p.m.; the oil pressure; correct running temperature; pick-up.
4. Degree of vibration at various speeds.
5. The valve clearance.
6. The correct spacing of the spark-plug electrodes.
7. The correct spacing of the magneto contacts.
8. The approximate size carbureter jets.
9. The air pressure used to force the gasoline.
10. The “feel” of the compression by turning the propeller.

Knowledge of Symptoms Required.—One who is not entirely familiar with engine construction will very rarely locate the troubles by haphazard experimenting. It is only by knowing the symptom, the causes of the symptom, and by systematically eliminating the causes or probable causes until the trouble is corrected that success is obtained when trouble shooting.

Local and General Troubles.—There are two kinds of trouble: (1) local and (2) general. Local trouble is confined to one or two cylinders or to one block of V-type engine. A dirty spark plug, for example, is a local trouble. It will cause one cylinder to miss but cannot affect the other cylinders. General trouble intermittently “skips” from one cylinder to another or affects all the cylinders, causing missing or a complete shutdown. A leaky intake manifold, for example, is a general trouble. It will cause all cylinders to miss, and if really bad, can prevent starting.

Sources of Trouble.—There are three main sources of trouble:

1. Carburetion.
2. Ignition.
3. Compression.

Other troubles might be called *subtroubles*. Example: An exhaust valve not seating is a local subtrouble of the main trouble, *compression*. Dirty contacts might be called a general subtrouble of the main trouble, *ignition*, because it is an ignition trouble and causes a general miss of the motor.

A Symptom.—The symptom of the trouble is the effect the trouble causes or the condition of the motor caused by the trouble.

Main and Subtroubles.—The first thing to be determined when trouble shooting is: What *main trouble* does the symptom indicate? Then: What *subtroubles* could cause the main trouble?

Order of Classification.—The main troubles will now be classified under Carburetion, Ignition, and Compression and an endeavor made to show the subtroubles, giving the method used to determine the trouble, the systematic elimination, and remedy.

CARBURETION

When General and Subtroubles.—Troubles of the carbureter are usually classed as general troubles, but on the V-type motor, where twin carbureters are used, they may be classed as local troubles when one block is affected.

Usual Symptoms.—The usual symptoms of carburetion trouble are a lean or rich mixture. When the mixture is lean, backfiring may be noticed in the carbureter and the motor will be found to fail to turn up to the proper r.p.m.; when distinctively rich, a rolling, irregularly running motor and exhausting black smoke, which has an offensive odor.

Indications of Lean Mixture.—To determine if the mixture is lean, close the choke valve partly. Notice speed of the motor if the speed increases. If it does increase, it is a positive sign that insufficient gasoline is being supplied the motor. Most mechanics at this stage would change the carbureter jets. In doing so, the motor would have to be restarted and tested again. To save the time of starting the motor

several times, start systematically and trace the gasoline from the tank to the jets in the following manner:

1. How much gasoline is in the tank?
2. If pressure is used, what is the pressure?
3. If no pressure is used, is the air vent open in the tank?
4. Is the gasoline line or the filter stopped?
5. Is the float level high enough?
6. Any water in the carbureter or the system?
7. Is the pressure from the float chamber to the jets stopped?
8. Are the jets stopped?
9. Any air leaks in intake manifold or its connections? If, after trying all the above subtroubles of the main carburetion trouble, a remedy is not found, then it is permissible to increase the size of the jets, which will undoubtedly cure the trouble.

Indications of Rich Mixture.—To determine if the mixture is rich, open the altitude adjustment slightly or hold the needle valve down tight. Notice the motor speed; if the speed increases, black smoke decreases, and the motor runs regularly, then the mixture must be rich. Since there is too much gasoline, the supply from the tank to the jets must be sufficient, but if the pressure were too great, it would cause the carbureter to flood, and we know that flooding will cause a rich mixture by causing too much gasoline to overflow the proper jet level.

Tracing Too Rich a Mixture.—Use the following system to trace the cause of rich mixture:

1. Is the pressure too great?
2. Is the float valve seating properly?
3. Is the float air tight?
4. Are the jet gaskets the proper thickness and in good condition?
5. Any other reason for flood, such as poor casting?

NOTE.—All the above subtroubles would cause flooding and, in turn, a rich mixture noticeable mostly at low motor speeds.

If no flooding is noticed, try:

6. Is the main air passage stopped?
7. Is the choke valve partly closed?

NOTE.—After eliminating all the above subtroubles and still finding no cure, then decrease the size of the jets, and the trouble will be remedied.

Apply Only Usual Process in Case of a Lean Mixture.—If, after trying the method prescribed for a lean mixture (see p. 281), no speed increase is noticed, do not attempt any elimination of carbureter troubles, because of the other troubles that give the same symptoms, but do not respond to the same method of determination given. Example: An air leak in the intake manifold or its connections will cause trouble by diluting the mixture in the manifold, especially at low motor speed, when the vacuum in the manifold is the greatest and also because a lesser quantity of mixture is flowing through the manifold.

Symptom Similar to a Lean Mixture.—Crossed magneto distributor wires will, at times, give a lean-mixture symptom but are recognized by the motor missing locally on two or more cylinders and, should the spark occur while the intake valve is open, will give a sharp backfire in the carbureter.

Inlet Valves Holding Open.—An intake valve could cause trouble similar to a lean mixture by sticking in its guide or by not closing properly, causing also a dilution of the mixture in the manifold and, in turn, a general miss.

Improper Exhaust-valve Timing.—An exhaust valve not opening properly would cause a back pressure when the intake valve opened and possibly cause backfiring at high speeds. It will give a lean-mixture indication but will not respond to the method previously stated to determine when the mixture is lean.

Preignition.—Preignition caused by carbon or a mistimed spark will sometimes cause backfiring by igniting the mixture when the intake is open.

General Mistiming of Valves.—The camshaft set too early will cause backfiring. If the exhaust valve closes and the intake opens before the piston has reached top center and before the burning gases are exhausted, then the mixture in the manifold will ignite and backfire.

Improper Compression.—Poor compression in one or more cylinders will give a lean-mixture symptom, especially at low motor speeds, but cannot be remedied by the lean mixture test.

Overoiling.—Too much oil in the cylinders will give a similar symptom to that of a rich mixture, making the motor roll, run irregularly, and emit a volume of blue smoke, especially after the motor has been throttled down some time. The burning oil will saturate the mixture. Speed the motor and then throttle down gradually. If the motor

continues to miss when throttled slowly, it may be a combination of both a rich mixture and too much oil, in which case, test for a rich mixture and decrease the oil pressure. If the motor runs for some time without missing when slowed down, that indicates that the mixture is good until saturated with oil, in which case, decrease the oil pressure.

Low Volatility of Gasoline.—A poor grade of gasoline will make the motor hard to start, overheat it, and possibly cause backfiring at high motor speeds, also throttle very poorly. If the motor must be started and better gasoline is not available, saturate a clean rag with gasoline so that the gas will not drip from the rag and place the rag in the main air intake of the carbureter; open the throttle about a third of the way. Then start the motor and withdraw the rag when it runs fast enough to carry on. This method will allow the lighter gases to be drawn from the rag and usually works very well. The reason that poor gasoline makes the motor heat and backfire is because it is slow burning. It continues to burn when the intake valve is open and ignites the incoming charge of gas.

Occurrence of Water.—Water in gasoline is of common occurrence. It will, if enough is present, make the motor impossible to start. When the motor is running, it will cause backfiring at high speed and cause stopping or missing when the motor is throttled. Water is heavier than gasoline and cannot be drawn through the jets by the same vacuum as gasoline. If only a small quantity, it can sometimes be removed by speeding the motor and clogging the choke when the motor is at speed. This will create a higher vacuum on the jets and draw the water through. Before the motor stops, open the choke and respeed to clean out the rich mixture. This should never be done if the motor is really cold, as the unburned gasoline due to the clogging on the choke will collect in the cylinders, destroy the lubrication of the cylinder walls, and possibly cause scoring. It will also work past the rings and dilute the cylinder oil. Do not rest until all the water is removed from the gasoline supply system.

Air Leaks in Manifold or Its Connections.—Leaks commonly occur at the joints and are caused by faulty gaskets, neglect to place gaskets, or faulty machining of the manifold flanges, preventing their being drawn tightly together all around the passage. The best gasket is a soft, compressible, and tough material. Rubber or asbestos gaskets

should not be used, as the gasoline will deteriorate them and cause leaking. Gaskets should never be more than $\frac{1}{16}$ inch thick. Thicker gaskets may cause the flanges to become sprung and cause a leak.

Worn Intake-valve Stems and Guides.—These commonly occur in older engines and affect the mixture at low motor speeds, causing missing and stalling.

Importance of Air Leaks.—Too much importance cannot be attached to air leaks, as a seemingly insignificant leak will cause serious difficulty in starting the engine and make it very sensitive to stalling. Should an engine stall while being flown close to the ground, it may place the aviator's life in danger and cause a serious accident.

Carbureter Changes.—It is essential to go over the entire engine before attempting any carbureter change, unless, of course, the action is such as to point directly to the carbureter.

Gasoline Economy.—Economy of gasoline is very important in airplanes, due to the limited carrying capacity. A gallon of gasoline saved may save the lives of the men flying. Therefore, it is important to keep the mixture as lean as possible and still obtain the motor's maximum r.p.m.

Changing Choke and Jets.—The following points are to be considered in changing the choke tube or jets:

1. If the choke tube is too large, the pick-up will be defective and cannot be bettered by the use of a large compensator. The motor will have a tendency to load up and at high speed run irregularly.

2. If the choke tube is too small, the effect is to prevent the motor from taking a full charge when the throttle is open fully, and the motor will not develop its proper r.p.m.

3. If the main jet is too large, irregular running, a characteristic smell from the exhaust, carbon, sooting of spark plugs, and excessive consumption of gasoline are the result.

4. If the main jet is too small, the results are a lean mixture at high speed, backfiring, and low r.p.m.

5. If the compensator is too large, there will be the same indications as in the case of the large main jet, except that the fault shows up at the lower motor speed.

6. If the compensator is too small, there will be a poor pick-up, a lean mixture at moderate speed, the motor will miss and try to stall at half-throttle opening.

Ability for Prompt Adjustment.—Do not play with the carbureter a long time. Carbureter trouble should first be determined and then adjusted. The adjustment should never take longer than it is necessary to take out the old jets and replace new ones.

IGNITION

Classification.—Ignition is classified as either general or local trouble.

Determination.—To find ignition trouble, first determine in what class the trouble is.

Occurrence of Local Trouble.—Local trouble is usually confined to one cylinder, although it may occur on two.

Local-trouble Test.—After classifying the trouble, if it is local trouble on the cylinder, take high-tension lead from the spark plug, hold within $\frac{1}{8}$ inch of the cylinder, observe the spark. (Test made with engine running.) If the spark jumps the gap, then stop the motor, take the spark plug from the missing cylinder, and change with the plug from another cylinder which did operate well, put the plug taken from the missing cylinder in place of the other plug. Start the motor and retest. If the miss changes to the cylinder where the plug was placed from the first missing cylinder, then the trouble is the spark plug. If the same cylinder continues to miss after the plugs are changed, then the miss is not due to ignition trouble. Examine the valves for clearance and compression.

Case of Short-circuited Distributor Block.—If, when the wire is held $\frac{1}{8}$ inch from the ground no spark or a very weak spark is observed, then disconnect the same high-tension wire at the magneto and see if the magneto is delivering a spark to that wire. If it is, lead wire is short-circuited. If it is not, and all other cylinders are receiving their proper sparks, then the trouble must be a short-circuited distributor block. This may be due to oil on the face of the block and to an internal short-circuit. Clean the block and try. If still bad, try a new block.

Local Incorrect Wiring.—When trouble is a two-cylinder local miss, it may be due to dirty spark plugs, short-circuited wires, or short-circuited distributor block but is most commonly due to the wires being attached incorrectly.

Spark Plugs.—Spark plugs can give local misses only but are sometimes very difficult to locate when missing only once in a great while. If the electrodes are set too far apart, the motor will be hard to start and will miss at high speeds; if too close, it will start easily but will

throttle very poorly. A setting of 0.018 to 0.025 is about correct for airplane motors. If the magneto is weak, they may be set as low as 0.010, but the magneto should be repaired or replaced as soon as possible. If the motor has a tendency to oil the spark plugs, a close setting will be found to keep the plugs clean longer.

Removing Porcelains.—Cracked porcelains are frequently due to carelessness of the mechanic. When taking plugs apart, the body of the plug should be held in a vise just tight enough to keep it in place, get a wrench that fits the porcelain binding nut, a socket wrench if possible, and be sure that the wrench does not slip.

When cleaning the porcelains, never use emery cloth or sandpaper, as either will scratch off the gloss, roughen the surface, and make the porcelain more susceptible to carbon. When putting a plug together, a new inside gasket should be used. Tighten the binding nut carefully, tightly enough to prevent leaks but not so tightly that the heat of the motor will expand the porcelain and break it. The reason a new gasket should be used is that it will prevent leakage without being tightened as tightly as an old one and allow more room for expansion. A new outside gasket should also be used for the same reason. Nothing will cause a plug to go bad more quickly than a leak around the porcelain, as the hot gases will overheat it and crack it.

Cleaning Plugs.—Plugs should be kept clean of carbon. It is impossible to keep the plugs very cool with water circulation, and a small particle of carbon may become incandescent and preignite the mixture. It is more difficult to clean spark plugs that do not come apart. To get good results, soak the plugs in kerosene, then scrape off the carbon and wipe dry.

Setting Electrodes.—Care should be taken not to bend the electrodes unless it is necessary to adjust them. They become brittle with age and break very easily. They should be scraped and examined very closely for defects of crystallization, and if burned badly, should be discarded. Porcelains should be examined thoroughly and replaced if they show any signs of being cracked.

General Trouble.—General ignition trouble may cause any cylinder to miss or cause failure of the motor to start.

Magneto Case.—When a high-tension magneto is used, the following trouble-shooting system has been used successfully in finding general ignition trouble.

High-tension Magneto System.—Disconnect all spark-plug wires. Hold one or more within $\frac{1}{8}$ inch of the cylinders. Have another man crank the motor over quickly as if to start it. Notice the size and color of the spark. If the spark jumps the gap and seems "fat," that is, if it has plenty of volume and appears to flame, the ignition system is no doubt all right as far as general trouble is concerned. If the spark appears "thin," only a faint blue spark without any volume, or if no spark appears, then the magneto is at fault. The next test should be made off the collector ring or from the lead from the high-tension winding before the current is led to the distributor. Take a piece of high-tension wire, fasten one end to the engine so that it will ground, hold the other end about $\frac{1}{8}$ inch from the collector ring or high-tension winding lead, and have another man crank the motor. If the spark is good, then examine the collector brush, the safety gap, the rotor pencil, the rotor, the rotor brush, and the distributor block for leakage to the ground or for poor contact. If no defect is found, replace each part with a new part until the trouble is remedied. A small leak is sometimes very difficult to find, and the replacing of parts will eliminate time. Go over the timing of the distributor in relation to the armature. The distributor brush should just make contact on the block segment with the spark retarded, when the contacts open and when the magneto is turned in the direction of rotation. If, when testing the high-tension circuit, no spark is delivered, then the trouble may be in the primary circuit. The primary is usually more often at fault than the secondary. All high-tension magnetos are made to furnish a spark when the switch is open. The primary circuit is grounded when the switch is closed. Should the wire from the breaker box to the switch become grounded, it would ground the magneto whether the switch were open or closed. Likewise, the switch itself may become short-circuited. The usual way to connect the ground wire to the primary circuit is through the breaker-box cover and it is insulated from the cover. Should this insulation become defective, the magneto may become grounded. To eliminate the breaker-box cover, the ground wire, and the switch, disconnect the breaker-box cover, be careful while cranking, and test for spark again at high-tension lead. If a spark is obtained, connect the breaker cover without ground wire and switch; try for spark. If there is no spark, then the trouble is in the cover. Attach the ground wire and switch in like manner if the cover is all right, until the trouble is located.

If, after eliminating the switch, ground wire, and breaker-box cover, no spark is obtained, then examine the breaker box. Clean the contact points, give proper clearance, make sure that they make proper contact. If the breaker points revolve, as they do on some types of magnetos, remove the primary contact screw before setting breaker clearance. This primary contact screw has two functions to perform: to hold the breaker assembly in place and to carry the primary current from the primary coil to the breaker points. It is insulated, therefore, by a fiber washer. Examine the washer for cracks. Should it be cracked and enough oil and dirt be in the crack, then the primary circuit will be grounded and no spark can be produced. Examine the insulating washers of the breaker arm and screw. Examine the ground brush in back of the breaker assembly. Replace the breaker assembly and primary contact screw, clean contacts, and adjust to the proper clearance. Test to see if the trouble has been located. If it has not been remedied, test for condenser trouble.

If several of the "plates" of a condenser become disconnected from the others, an arcing at the breaker points will be seen when the motor is cranked. *This is a sure sign of condenser trouble.* If the condenser "plates" are grounded, no spark will occur at the breaker points, and neither will a high-tension spark be produced. The only thing to do in this case is to try a new condenser and test for spark. If spark is still lacking, remove the magneto from the motor, test the magnets for strength and for reversed polarity. The magnets, if good, should hold each other when the opposite poles are placed together and held by one magnet horizontally. The magnets should never be left off the magneto unless a keeper is placed across the ends to prevent them from demagnetizing. The placing of magnets end to end so that they will attract each other, or the opposite poles together, will serve the purpose of retaining the magnetism. The strength of the magnets can usually be determined before the disassembly of the magneto by the feel of the resistance offered by the magnets when the magneto is turned by hand. If the magnets are found to be weak, assemble the magneto and send it to the magneto repair department for an overhauling. If the magnets are good, then the trouble must be in either the primary or secondary winding, in which case, send the magneto to the magneto repair department. Or put in a new armature shaft or replace the induction coil, depending upon the design of the magneto being repaired.

COMPRESSION

Classification.—Compression trouble can be local or general: local, when the valves or rings of one or several cylinders are bad; general, when the grade of oil is poor or when the camshaft is out of time.

When Poor Compression is Noticeable.—Poor compression in several or all cylinders is most noticeable when the motor is throttled down. Unless several or all cylinders are very poor, very little difference will be noticed in the r.p.m.

Methods Employed.—There are two ways to determine which cylinder is lacking in compression.

1. Turn propeller, notice valves, and watch which cylinder is compressing.
2. Take out all spark plugs, insert one, try compression of that cylinder. Then take out plug after test and try another cylinder, and so on, until all are tried.

Warm Motor before Testing.—To test all cylinders, warm the motor, make sure that it is safe—it is best to disconnect all spark plugs—and turn the propeller in the direction of rotation, noticing the resistance offered by each cylinder as it compresses. All cylinders should cause equal resistance.

Further Inspection through Good Compression.—If all cylinders have an equal amount of compression and the resistance noticed is correct for the type of engine worked on, further inspection is still necessary. An exhaust valve so gummed or carbonized as to close slowly when the motor is running is a cause of trouble, sometimes not found when turning the propeller by hand. It is usually noticed by a popping sound in the exhaust. If no popping sound is noticed, the "feel," when cranking, is good, and the motor throttles equally on all cylinders, then the compression may be considered good.

When to Examine Timing.—If the "feel," when turning the propeller, is poor on all cylinders, examine the timing and clearance of valves, and if they are not right, correct. If right, remove all spark plugs and insert a small quantity of cylinder oil in each cylinder, replace the plugs, and try again for compression, if compression is improved. Remove a small quantity of oil from the sump for examination. If the oil appears good, then the trouble may be due to too much gasoline in the cylinder from overpriming. In each case, the insertion of oil through the plug

hole is all that is necessary. If the oil is black, feels gritty, and seems very thin, replace with fresh oil.

The Case of Piston Rings and Excessive Oiling.—Poorly fitted or broken piston rings usually show up on one or several cylinders by pumping cylinder oil and are usually detected when turning the propeller. Piston rings can be fitted to hold compression and yet pump oil, so lack of compression cannot be blamed on the rings when pumping oil, unless the valves are known to be good. In case of broken rings or rings pumping excessive oil, the motor will have to be removed from the plane and overhauled.

Excessive oiling of one cylinder may be due to several causes.

1. If the rings fit the walls poorly.
2. If the rings fit the piston grooves poorly.
3. If the cylinder is scored.
4. If the valves are not seating properly.
5. If the connecting-rod bearing of that cylinder is very loose, or the oil grooves very deep, excessive oil will be thrown up in the cylinder where the pressure-feed system is used. This is noticed on V motors, when two cylinders opposite each other give the same symptom of overoiling.

6. If the valves are not operating properly.
7. If the pistons are poorly fitted. Pistons, when too loose, will allow too much oil on the cylinder walls, and this oil will force by the piston rings, giving the impression that the rings are bad. Poorly fitted pistons usually give a rattling sound when the motor is throttled or running at moderate speed. Overoiling usually results in poor compression by carbonizing the valves and causing them to seat improperly.

Carbonized Valves.—Carbon on the valves is the most common of compression troubles. It is due to overoiling, a rich mixture, or a natural deposit from long service without cleaning. It is impossible to prevent this deposit, but it may be decreased by keeping the mixture as clean as possible, using good oil, changing the oil often, and injecting kerosene into the combustion chamber while the engine is warm after each flight.

Warped or Burned Valves. Warped valves are usually due to an excessive deposit of carbon on the face of the valve, poor material in the valve, or the stopping of a motor while very hot. A motor should never be stopped immediately after running at full throttle but should be throttled down until it cools gradually to its normal heat. Rapid

cooling of a motor is just as harmful as rapid heating. Rapid cooling usually results in warped valves. Burned valves are the result of running a motor which has warped or carbonized valves. Burned and warped valves can also be the result of being poorly ground in. Should a slight leak be left, the burning gases, when on the power stroke, will rush through the opening and, in time, make the opening much larger.

Slow-burning Mixture.—A slow-burning mixture caused by poor-grade gasoline, a lean mixture, or a rich mixture will cause valve trouble, overheating the motor and leaving a carbon deposit.

Overheating.—Poor-grade oil, a rich mixture, a lean mixture, late spark, a new or tight motor, and lack of water or poor circulation usually give valve trouble first and ruin the complete motor in short time.

Weak Valve Springs.—Weak valve springs usually occur on the exhaust side from overheating. They are most noticeable at low motor speed. When on the intake stroke, if the exhaust-valve spring is weak, the suction created by the downward plunge of the piston will cause the valve to open partly, and a portion of burned gases will be drawn in from the exhaust manifold, causing a dilution of the mixture and a poor explosion. They can usually be detected by a popping sound in the exhaust manifold. If a screw driver is placed under the spring and more tension created, the cylinder giving trouble can be located by the ceasing of the popping noise.

Defective Camshafts.—Defective camshafts are very rare and very difficult to diagnose on account of the many symptoms that they can create. Should one be suspected, check the timing of each cylinder separately.

Defective Valve-operating Mechanism.—Defective valve-operating mechanism, such as a defective cam follower, is rare and hard to locate. It usually shows up when it is impossible to get the proper valve timing. Tight rocker-arm bearings will cause the valve to hold open too long and result in a general miss when an intake valve is affected and a local, when an exhaust.

Conclusion.—We have now gone over a few of the most common troubles and explained their separate symptoms and causes, but in a great many cases, when trouble shooting, it will be found that several troubles will happen at the same time, and perhaps a complicated symptom will be the result. In such a case, it will mean that the trouble

will be harder to diagnose and locate. Should a complication of troubles be suspected, time will be saved by making a complete inspection of all units. Trace out the ignition system, gasoline supply, compression, valve timing, etc. Eliminate troubles as found, and when all are thought to be found, then start the motor. If proper inspection has been made, the motor should, after a few slight adjustments, run perfectly.

ENGINE INSPECTION BEFORE FLIGHT

Airplane engines must be inspected before each flight in a systematic way, that takes little time but covers everything thoroughly and efficiently. The inspector must keep in mind at all times that his inspection is not only to eliminate troubles which are found but also to prevent troubles occurring. The old saying, "An ounce of prevention is worth a pound of cure," applies especially well to airplane inspection and should be followed.

The first requirement of an airplane mechanic is reliability—there must be no guess work about anything that is part of an airplane—everything must be right before the machine is permitted to leave the ground.

Although the general principle of airplane engines is the same, each has its own peculiarities which must be memorized by the inspector. He must know engines in general and as many different types as possible. Before starting engine, check as follows:

Ignition System.—Trace ground wire from magneto to switch, examine it for shorts or places where it may be chafed or likely to chafe or short. Examine switch for proper action. Take off breaker-box cover and watch operation of breaker as motor is turned over by hand. Clean points and reset if necessary. Be sure there is not too much oil in box; it should be dry except for a thin coating on the cam. Wipe out distributor block with clean cheesecloth that has a few drops of thin oil on it. If distributor segments are burned or blackened, rub off black with a lead-pencil rubber. Examine pencil for cracks and shorts. Examine pencil brush for proper contact; if burned or glossed, use fine sandpaper and sand off until gloss disappears and brush makes proper contact. Examine collector brush and sand down if necessary. If brush is worn short, replace it. All wires must be tight in their connections and connections tight in distributor block and locked in place. Take out spark

plugs, clean, examine for broken porcelains, and set gaps. Set plugs aside until valves have been checked, as it is easier to turn propeller without compression in cylinder. Examine breaker-box advance and test mechanism (if used) for free and proper performance. Try for spark by holding several wires about $\frac{1}{8}$ inch from cylinder and spin propeller (plugs out). All connections must be tight and clean. All oil-soaked wires must be replaced. Wires must not chafe or be placed near exhaust ports or pipes. Wires must not be stretched so tight that vibration of motor breaks or pulls off connection. See that no strands are broken where wire is attached to plugs. Go over timing and check for proper setting.

Compression System.—Check opening and closing of each valve and regulate clearance accordingly. See that valve mechanism is working properly and that rocker arms and valves work freely. Make sure that tappet adjustments are securely locked. Test tension of valve springs. Replace spark plugs and try compression by rotating propeller.

Gasoline System.—Examine tank setting and see that it is full. Examine tank for leaks. If gravity system is used, check air vent. If pressure, see if tank holds pressure. Squirt a few drops of oil around tank-filler cap and around pressure regulator and watch for leaks. Inspect gasoline line for leaks. Take plug from sediment trap and inspect for water and unusual amount of dirt. Replace plug. Disconnect gasoline line at carbureter and inspect flow of gasoline. Replace line, remove plugs under compensator jets, and let gasoline flush through. Turn off gasoline, remove jets, and check if proper size for motor. See that jet gaskets are O. K. Should any water be found in system, drain all gasoline and strain through chamois skin. Try out throttle controls for full opening and closing. Examine control wires for chafing. Turn on gasoline; watch for carbureter flooding.

Air System.—Inspect choker valve, see that it opens and closes correctly. Examine carbureter intake for stoppage. Sometimes a screen is used over air intake, and it will get clogged with dirt. Check all nuts on manifold joints and test for possible leaks with oil. Squirt oil around joints, then turn propeller and watch for bubbles at joints.

Water System.—Examine water for presence of oil. Fill radiator. Check all hose and pump connections for leaks. Examine condition of all hose. If oil-soaked or soft, replace. When tire tape is used on hose, it should be shellacked. See that all draincock handles are

turned down and tight. All airplanes carry just sufficient water, and should a slight leak occur or be allowed to pass, it would be only a short time before the motor overheated.

Oil System.—Remove sump screen, clean, and replace. Fill with required amount of fresh oil. Examine all oil pipes for leaks and make sure they cannot vibrate and break loose. Examine crankcase for leaks. Oil all moving parts with oil can.

General.—Check up propeller nuts and all lock springs and safety wires. See that propeller tracks within $\frac{1}{8}$ inch. Examine propeller for possible splitting or fraying. Go over all nuts and see that they are tight and properly locked, touching each with fingers in order not to skip one.

After Starting Engine.—Run slowly until warmed, allowing all parts to expand equally and oil to warm and circulate properly.

Speed up and adjust oil pressure to factory specifications.

See that water is circulating and motor does not heat.

Speed motor slowly, noticing degree of vibration at various speeds.

Test motor at full speed and then at throttled speed.

If trouble appears and then disappears, do not rest until it is found and eradicated, for it may later appear, especially at high altitudes.

Conduct entire inspection with aim of preventing trouble and do not quit until conscience is clear.

Classifying Troubles.—When a motor is not working right, the trouble must be classified and a decision reached as to what the motor is doing. For example: "Does it miss?" and "Cut out," "Slow down," "Backfire," "Fail to start," "Loud reporting at the exhaust," "No oil pressure," "Knock," etc. Then : At what speed does the trouble occur? Many troubles occur only at certain speeds, and therefore note should be made of the speed at which the trouble occurs.

General and Local Troubles.—Notice, if possible, what part of the motor is giving trouble, for example: On a V-type motor, is the right side or the left side missing? Notice *which* cylinder is giving trouble, and then the trouble can be found comparatively quickly. Some troubles can cause the whole motor to go wrong but could not cause just one cylinder to give trouble. Such troubles could be called "general" troubles. Another kind can cause one or two cylinders to miss or give trouble but could not cause a general trouble; these are called "local" troubles.

Elimination of Troubles.—Suppose that the motor is missing. Now, in addition to an observation of the speed at which the motor is missing, the nature of the miss should be observed. For instance, is one cylinder missing occasionally, one cylinder missing steadily, one side of the motor cutting out, or the whole motor cutting out as though the switch were being intermittently pulled? Or is it a scattering miss, which means first one cylinder on one side and then another cylinder elsewhere, but not missing regularly? Suppose that one cylinder is missing occasionally. At what speed does the miss occur? Suppose that it occurs at low speed. What can cause a motor to miss only at low speed on one cylinder? Any of these causes will do it: short-circuited spark plug, plug gap too close, poor compression, air leak around the intake-valve stem, or a weak exhaust-valve spring. How can it be determined which of these troubles is causing the miss? By eliminating the most common causes until the trouble is found and remedied.

Diagnose Trouble by Symptom.—It is necessary, when shooting trouble, to diagnose properly the trouble by the symptom and to eliminate troubles one at a time until the right one is found. It would be foolish to examine the magneto if the symptom indicated a lack of gasoline.

List of Symptoms and Troubles.—The following paragraphs contain lists of symptoms with the troubles that will cause them. The student should acquaint himself with these symptoms and, in a short while, should be able to diagnose troubles by symptoms and eliminate a particular trouble in a very short time.

If Engine Fails to Start:

It may be due to any of the following causes:

1. Lack of gasoline.
2. Primed too much. Rotate engine backward several times to clear it of excessive gas or turn engine in direction of rotation with throttle wide open.
3. Insufficiently primed.
4. Throttle too wide open. Or not enough.
5. Faulty spark.
6. Lack of compression.
7. Camshaft out of time.
8. Ignition out of time.
9. Cold motor.

If Engine Stops:

1. Lack of gasoline.
2. Faulty spark.
3. Overheated.

Lean (or Rare) Mixture:

1. Water in carbureter.
2. Dirt in jets.
3. Poor gasoline supply (dirt in line or not enough pressure).
4. Level low in carbureter.
5. Backfiring.
6. Air leak.
7. Jets too small.
8. Altitude adjustment open too far.
9. Venturi tube too large.
10. Low-test gasoline.

Scattering Miss (one that jumps from one cylinder to another):

1. Lean mixture.
2. Rich mixture.
3. Faulty spark.
4. Water in carbureter.
5. Air leak in intake manifold.
6. Intake valve holding open.
7. Valve springs weak.

Motor Will Not Develop Proper Speed Yet Does Not Miss Fire:

1. Mixture slightly too lean.
2. Mixture slightly too rich.
3. Camshaft set too late.
4. Ignition set too late.
5. Poor grade of oil (or oil too long in use).
6. Overheating.
7. Tight motor (one that has just been overhauled or is new).
8. Venturi tube too small.
9. Insufficient throttle opening.
10. Excessive carbon.
11. Poor grade of gasoline.
12. Valves not opening far enough, due to valve seating too far in cylinder.

Missing Fire at High Speed on One Cylinder:

1. Short-circuited spark plug.
2. Short-circuited distributor wire.

3. Short-circuited distributor block.
4. Spark-plug gap too wide.
5. Weak exhaust-valve springs.
6. Poor compression.

Missing at Low Speed on One Cylinder:

1. Short-circuited spark plug.
2. Spark-plug gap too close.
3. Poor compression.
4. Short-circuited plug wire.
5. Short-circuited distributor block.
6. Air leak around intake-valve stem.
7. Weak exhaust-valve spring.

Causes of Excessive Carbon in Cylinders:

1. Use of too much oil.
2. Bad piston rings.
3. Poor grade of cylinder oil.
4. Rich mixture.
5. Motor run long while without cleaning.
6. Poorly fitted pistons.

Result of Excessive Carbon in Cylinders:

1. Preignition.
2. Overheating.
3. Knocking due to carbon; in time will loosen bearings.
4. Motor will not develop speed.

Backfiring in Carbureter:

1. Cold mixture.
2. Lean mixture.
3. Air leak in manifold or around intake valves.
4. Valve springs weak.
5. Distributor wires attached wrong.
6. Magneto timed wrong.
7. Exhaust valve not opening or not far enough.
8. Camshaft set too early.
9. Rich mixture.
10. Overheating.
11. Carbon.
12. Low-test gasoline.
13. Venturi tube too large.
14. Intake valve sticking (gummed or tight in guide).

How to Detect Mixture by Color of Exhaust:

1. Long red and yellow flame indicates rich mixture.
2. Short, irregular, light-blue flame indicates lean mixture.
3. Black smoke indicates mixture entirely too rich.
4. Blue smoke means too much oil is being used.
5. Quick blue flame without yellow tip means correct mixture

Causes of Rich Mixture:

1. Carbureter flooding.
 - a. Leaky float.
 - b. Level too high.
 - c. Gaskets under jets bad.
 - d. Hole in carbureter casting.
 - e. Float valve not seating; dirt under seat.
 - f. Air pressure too high.
2. Jets too large.
3. Air intake stopped up (or choke valve closed part way).
4. Venturi tube too small.

Loud Reporting Out of Exhaust:

1. Preignition.
2. Camshaft set too early.
3. Rich mixture.
4. Spark too late.
5. New or stiff motor.
6. Faulty spark.

Preignition:

1. Carbon.
2. Overheating.
3. Rich mixture.
4. Magneto out of time.
5. Wires from distributor crossed or lead to wrong cylinder

Faulty Spark:

1. Breaker points not spaced properly.
2. Breaker points burned or corroded.
3. Condenser short-circuited or broken down.
4. Magnets weak or crossed.
5. Collector brush worn out or dirty.
6. Distributor brushes worn out or dirty.
7. Collector ring or commutator short-circuited or dirty.
8. Distributor block short-circuited or dirty.

9. Primary winding short-circuited or broken down.
10. Secondary winding short-circuited or broken down.
11. Distributor pencil short-circuited.
12. Safety gap too low.
13. Distributor out of time with primary circuit.
14. Poor connection between secondary and collector ring.
15. Ground wire or switch short-circuited.

Overheating:

1. Spark set too late.
2. Poor water circulation.
3. Rich mixture.
4. Poor oil circulation.
5. Oil too thin or cold.
6. Lean mixture.
7. Camshaft set too late.
8. Running at low speed too long.
9. Poor compression.
10. Tight bearings or pistons.
11. Bearings or pistons out of line.
12. Excessive carbon.

Poor Compression:

1. Valves not adjusted properly with respect to clearance.
2. Valves warped.
3. Valves caked with carbon.
4. Valve stems bent.
5. Valves gummed or sticking.
6. Leaky cylinder head, spark plug, or valve-cage gaskets.
7. Insufficient oil supply, or oil has been used too long.
8. Rocker arms too tight.
9. Valve springs broken or weak.
10. Camshaft out of time.
11. Rings not seating properly or broken or weak.
12. Cylinders scored.

Result of Rich Mixture:

1. Excessive carbon formed in cylinders and on valves.
2. Overheating of motor.
3. Motor will gallop and not develop proper speed.

Result of Lean Mixture:

1. Motor will backfire and may catch fire.
2. Will burn valves.

3. Motor will not develop proper speed.
4. Motor will stall or "die" easily.

Result of Too Much Oil:

1. Will cause engine to misfire by short-circuiting spark plugs.
2. Will create excessive carbon.
3. Will get on insulated wires and cause short-circuits.
4. Will get on cloth-covered parts of plane and cause deterioration.
5. Will vaporize, and vapor will interfere with proper combustion, causing effect of too rich a mixture.

No Spark:

1. Primary circuit grounded.
2. Secondary circuit grounded.
3. Grounded ground wire.
4. Switch grounded.
5. Condenser open or short-circuited.
6. Magnets crossed.

When Engine Knocks:

Knocks such as the following are caused by various defects in the engine:

Loose Connecting-rod Bearings.—A rather sharp metallic sound noticeable at low motor speed.

Loose Main Bearings.—A dull heavy knock accompanied by vibration. Noticeable when motor is picking up speed or when throttled down.

Loose Wristpins.—A sharp metallic sound. Very pronounced when motor is throttled down.

Loose Pistons (Pistons Slap).—A rattling sort of sound, most pronounced when engine is running under light load.

Ignition Advanced Too Far.—A very sharp knock without much volume of sound. May be stopped by retarding spark.

Carbon.—A similar sound to spark knock but cannot be stopped by retarding spark.

Labor Knock.—Caused by engine running hot or by lean mixture.

Oil Pressure Too High:

1. Adjustment.
2. Bearings set too close.
3. Oil grooves in bearings not deep enough.
4. Oil pipe kinked or bent.
5. Bypass stuck closed.
6. Too much oil in system.
7. Extra-heavy oil.
8. Oil cold or frozen.

Rapid Rise in Oil Pressure:

1. Bearings getting too tight, due to overheating.
2. Stoppage in system between gage and bearings.
3. Too much oil in system.
4. Oil cold or frozen.

Oil Pressure Too Low:

1. Insufficient oil.
2. Regulator not set properly.
3. Oil too thin or cold.
4. Leak in feed pipes.
5. Bearings too loose.
6. Bad gage.
7. Gears in pump worn.
8. Overheated motor.

Rapid Decrease in Pressure:

1. Leaky or broken feed pipe.
2. Stoppage in line between pump and gage.
3. Broken pump gears or shaft.
4. Burned-out bearing.
5. Running out of oil.
6. Overheating of motor.

SECTION VI

THE PROPELLER

The propeller of the airplane is very similar to the propeller of a vessel in many ways. It must have sufficient thrust, or pull, in the case of a tractor, to overcome the resistance of the machine at its flying speed. The propeller itself introduces some resistance due to the skin friction as it revolves in the air, the resistance of the center of the propeller, eddies in the air caused by the whirling of the propeller, and cavitation, or the tendency to produce a cavity or partial vacuum in which it revolves. This increases with the propeller speed and decreases the speed of the machine. For this reason, propellers are often geared down from the engine so as to secure high power from the motor with the desired slower speed of the propeller. The pitch angle, or angle of incidence, of the propeller can be considered in much the same way as that of the planes, as the blades are, in reality, small planes which revolve instead of being forced straight through the air, as with the wings of the machine.

The thrust of an airplane propeller, according to Chas. W. Rauch, is generally considered equal to 3 pounds for each horsepower of the engine driving it. This is based on an 80 per cent efficiency of the propeller at air speeds of about 100 miles per hour. On this basis a propeller driven by a 200-horsepower engine at 100 miles per hour has a thrust of 600 pounds.

The mechanical strength of the propeller blades is a serious consideration which affects the design very materially. For the propeller is subjected to very severe stresses due to the bending of the blades from the hub outward, the centrifugal force, and also the shocks due to the impulses of the engine, even though these seem to be practically continuous in a multicylinder, high-speed engine. These impulses tend to loosen the propeller in its flanges and are credited with being the cause of charred hubs which are sometimes found when the propeller is taken off its shaft. These various problems demand great care in both design

and manufacture, especially with the wooden propeller. Wooden propellers are built up from layers of carefully selected wood, glued together with the utmost care and carefully shaped to templates which gage the exact contour at various points on the blade.

Propellers of all kinds, both for water and air service, have a certain amount of slip or lost motion. A propeller with a pitch of 10 feet, which means that it should advance the machine 10 feet for every revolution if there were no slip, may advance only $7\frac{1}{2}$ feet. This means a slip of $2\frac{1}{2}$ feet or 25 per cent.



FIG. 1.—Twisted type Curtiss-Reed metal propeller.

As the outer end of the propeller travels faster than the points nearer the center, the pitch angle changes just as in the case of a thread cut on a bar of steel. This can best be noticed on a small screw with a coarse pitch where it will be noticed that the angle at the bottom of the thread is much sharper than at the top.

At the present time, metal propellers have largely succeeded the more conventional wood propeller, although the latter has by no means been abandoned. Both aluminum alloys and steel are being used in metal propellers.

Metal propellers are made of the strong drop-forged aluminum alloys and heat treated to secure the strength desired. The tensile strength is from 55,000 to 60,000 pounds per square inch. The Curtiss-Reed propeller is made from aluminum alloy, and in two forms (Figs. 1 and 2). Both are solid from end to end. The earlier form, Fig. 1, is made from a slab of duralumin, shaped to the desired form and the blades twisted to the proper pitch. This bolts to a flanged hub on the engine shaft. The later design is of forged duralumin and is equipped with a steel sleeve that is keyed to the propeller and which also serves as a propeller hub. The propeller is normally furnished with this sleeve in the hub.

In mounting the propeller on the crankshaft, extreme care should be exercised to clean the shaft and the hole in the sleeve, and lubricate the crankshaft, the hole in the sleeve, and all threads with cylinder oil or the special lubricant furnished with the propeller. *Do not use graphite in any form.*

Push the propeller, with sleeve installed, onto the hub, by hand. Start the attaching nut internal threads on the crankshaft about one-quarter to one-half a turn before starting the external threads on the sleeve. Screw up the nut, tightening as tight as possible with a 4-foot, $\frac{7}{8}$ -inch bar. The tighter the propeller is put on the easier it will come off later. If the operation has been properly done, the holes for the locking pin will line up and this pin can be inserted. If the holes do not line up, it will be necessary to unscrew the nut and start the

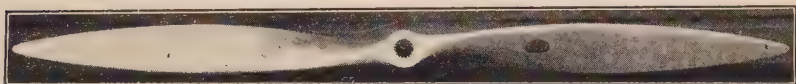


FIG. 2.—Forged type Curtiss-Reed metal propeller.

threads on the crankshaft a little further before starting the outer threads in the sleeve, or vice versa. If the propeller does not track within $\frac{1}{8}$ of an inch, it is an indication that the blades are bent, since the propeller has been carefully tracked, with the sleeve installed, at the factory. If the sleeve, for any reason, has been removed and the propeller does not track, it is possible that it can be corrected by removing the sleeve and turning it around 180 degrees from its original position.

The propeller used on the Wasp motor is of the direct-splined type, *i.e.*, splines in propeller material in direct contact with the crankshaft. Due to the relative softness of duralumin, care should be taken not to “burr” up splines in hub.

A tube of “antiseize” compound is supplied with each new propeller of this type for use on the crankshaft in place of oil.

If roughness or vibration should develop, check first to see that it is not due to loose bolts or slack wires in the engine section. Next, check to see if the blades have been bent. This check can be made by turning the propeller through 180 degrees and noting if the two-blade tips

track within $\frac{1}{16}$ inch. If this does not locate the trouble, remove the propeller and check it thoroughly for balance, track, and blade angle.

The Standard Steel Propeller Company makes an adjustable blade propeller with a steel hub as shown in Fig. 3, the hub being seen in Fig. 4.

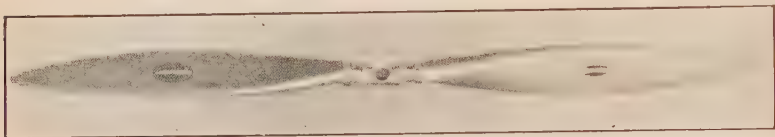


FIG. 3.—Standard steel adjustable propeller.

These hubs are made for two, three, and four blades, the three-way hub in Fig. 5 showing how the blade is locked in place by the two abutments and centered by the plain diameters at each end of the socket in the

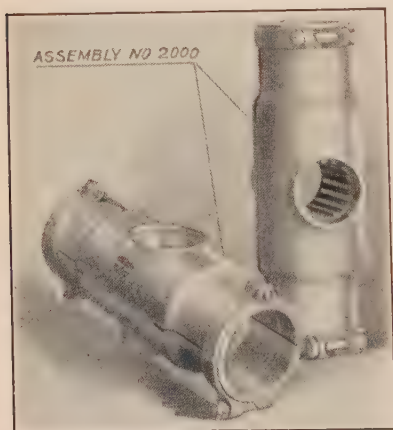


FIG. 4.—Standard two-blade hub for engines from 500 to 800 horsepower.

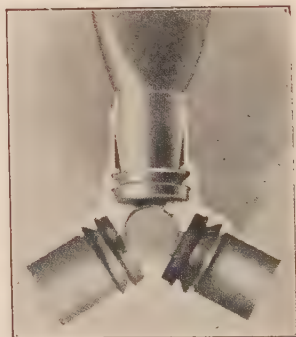


FIG. 5.—Blade end in three-way hub.

hub. The hub is in halves, held together around the blade end by hinged clamps at the end of each blade opening into the hub. The hubs are of forged chrome vanadium steel, heat treated for a tensile strength of 130,000 pounds per square inch. The clamps and bolts are also of alloy steel, the bolts having a fillet to prevent localizing the stress under

the head. Should a bolt be lost, it is not safe to replace it with an ordinary commercial bolt as such a bolt will not have the necessary strength.

Two advantages are claimed for propellers having separate blades; ease of replacement in case of damage and the ability to adjust the pitch to suit different conditions and different engines. If, for example, it is necessary to get a plane out of a small field, the pilot can set the propeller at a low pitch angle which will allow the engine to turn up faster and get the plane off the ground in a shorter distance, even at the expense of speed in the air. On the other hand, the pilot can economize on fuel by setting the propeller at a high angle and so slow down the engine at full throttle. No propeller adjustment should be made, however, without thoroughly understanding the theory fully. For racing or high-speed flying the propeller should be set at an intermediate angle, and checked by readings of the air-speed meter.

ADJUSTING THE PITCH

The hub ends of the blades have a clearance of 0.003 to 0.005 inches so that they can be turned by loosening the hub clamps, and tapping the propeller near the hub, using a rubber or wooden mallet, until the desired setting is reached. The hubs are marked as in Fig. 6 to enable both blades to be set at the same angle. After adjusting, the clamping ring should be pressed outward by hand against the shoulder on the end of the hub and then tightened with the bolt. This is important as the position of the clamping ring affects the balance of the propeller. The correct position can be determined by moving the clamping rings until the arrows on the rings are in a direct line with similar arrows on the hub. The best method for setting the blade angles is by means of a protractor and checking plate as in Fig. 7, but if one of these is not available the scale on the hub will be found quite satisfactory. On a propeller of average size the setting is usually specified at a distance of 42 inches from the axis, or center of the propeller shaft. On very large or very small propellers both the angle and the radius at which it is to be measured is specified.

When it is desired to change the engine speed by changing the pitch of the propeller it will be found that there is a change of approximately 60 r.p.m. for each degree of movement of the blades. This holds good for

either an increase or decrease of speed, and enables the same propeller to be used on different engines by adjusting to suit the speed and power

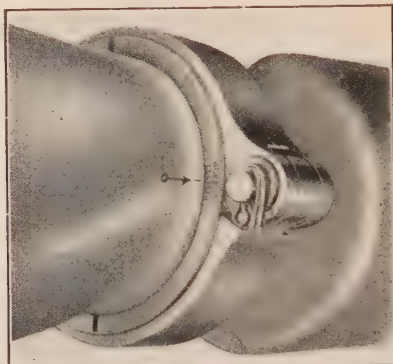


FIG. 6.—Close-up view of scale on hub.

of each. The ability to do this reduces the number of spare propellers that it is necessary to carry.



FIG. 7.—Protractor and checking plate.

Perfect balance in propellers is necessary to prevent vibrations that are detrimental to both engine and plane. Static balance is

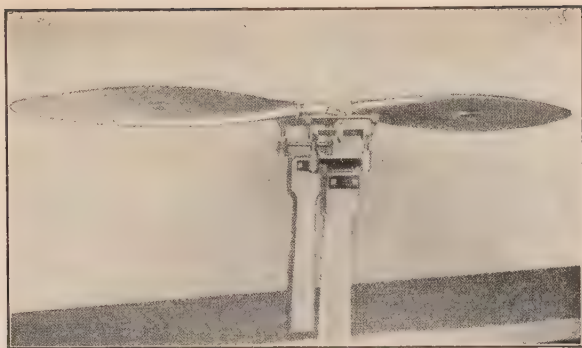


FIG. 8.—Horizontal balance of propeller.

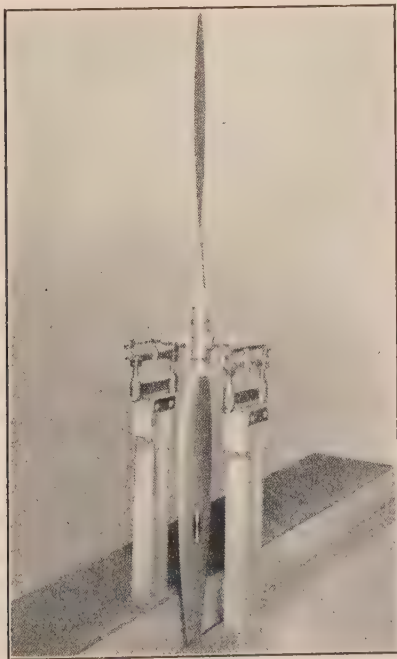


FIG. 9.—Vertical balance of propeller.

easily checked on balancing ways, with a mandrel through the propeller hub. A convenient form of balancing way is shown in Fig. 8. The knife-edge strips are adjustable and must be level when in use. The propeller should remain stationary in any position. If out of balance, the light blade is removed and a small amount of heavy metal placed in the hole at the hub end of the blade. If the unbalance is slight, a coat of varnish or enamel on the light blade may correct it.

Balancing the propeller in the vertical position, Fig. 9, can be done by shifting the clamping rings around the hub. Moving the bolt end of the clamp toward the light side will throw more weight on that side and enables very accurate balancing to be done.

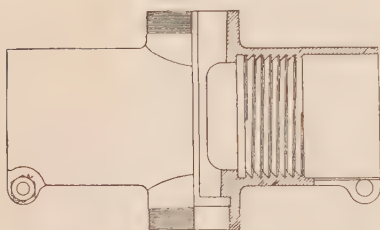


FIG. 10.—Propeller hub designed for engines of less than 200 horsepower.

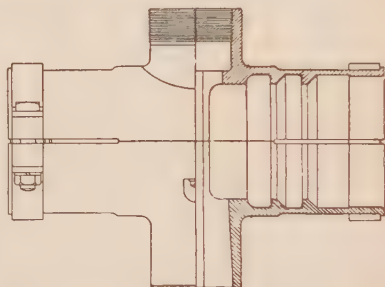


FIG. 11.—Propeller hub designed for engines of 200 horsepower and above.

The blades should also be of the same length and track within very close limits. Both blades should be at the same angle within a small fraction of a degree.

Once balanced, a propeller should need little attention to balancing until enough metal has been eroded or chipped away to change the weight distribution. This condition is apparent as soon as it occurs, and the remedy is obvious.

Whenever there is any sign of pitting at the leading edge of the blade, it must be attended to immediately. If the pitting is at all bad, the rough edges must be smoothed down with a fine file, the whole leading edge smoothed down with emery cloth and finished with crocus cloth.

When blades are damaged, due to bad landing, etc., it is often possible to straighten them so that they may be continued in use. In order to do this, however, the blades should be annealed first and heat treated

again after straightening. The blades must then be etched with a suitable solution and carefully examined for cracks before being put back into service.

Welding should never be attempted as the extreme heat destroys the strength of the alloy. It is best to return the blades to the makers for repairs. The best protection for aluminum-alloy propellers is a thin coat of oil applied with an oily rag. This should always be done after the surface has been disturbed with emery or crocus cloth.

The micarta propeller is less affected by exposure to salt or fresh water than either wood or aluminum. The density of micarta is approximately one-half that of aluminum, a propeller for engines from 150 to 210 horse power weighing 54 pounds.

The design of the hub for micarta propellers varies with the power to be delivered. For use with engines of less than 200 horsepower the ends of the blades are screwed into the hub, using a buttress thread as in Fig. 10, and clamping the blade by means of the split hub shown. For larger engines the screw thread is replaced by two heavier abutments inside the hub and a clamping ring is used on the outside, as in Fig. 11. This is made clear by reference to Fig. 12 which shows a blade in position, the complete propeller being seen in Fig. 13.

The Westinghouse Electric and Manufacturing Company has made recent improvements of the bakelite-micarta propeller which have proved very successful. This propeller is now made with separate blades similar to the variable-pitch metal propeller just described.

The laminations are placed in the mold having the exact angle and then pressed to final shape in a large press having a high load capacity. The material is heated during the process by steam coils to a temperature of some 350° F., the combination of pressure and heat first cementing and then congealing the material into a solid mass. The molding requires 3 to 4 hours.



FIG. 12.—Blade and section of hub of large propeller.

The molds must be machined very accurately, as upon this depend the polish and finish of the propeller itself. Little other work need be done to the propeller.

Micarta has a hard, polished surface and is proof against cold or heat in any degree likely to be encountered in service. It is not affected by weather, by water either salt or otherwise, or by oil. Bullets fired at a micarta propeller at full speed pierce a clean hole, without shattering or splintering. The micarta propeller with detachable blades is from 5 to 10 per cent lighter than an equivalent aluminum-alloy propeller. If designed as a single piece, without detachable blades, the weight is the same as that of an equivalent wood propeller.



FIG. 13.—Adjustable two-blade micarta propeller.

TESTING THE SHAPE OF BLADES

In testing the shape at various points, the propeller is laid on an iron block having a central stud at right angles to it, this stud representing the propeller shaft. This allows the templates to be placed on the blades at the desired intervals, these intervals being marked on the iron plate itself. The angle of the flat or nearly flat surface can also be readily measured. A surface gage is likewise used very carefully to test the height of various portions of the blade from the testing plate on which it rests. The pitch of a propeller can be measured by reversing this process, *i.e.*, measuring the pitch angle at various points and laying these off on a chart. Such a chart should show a uniform change of pitch from the hub out.

A method of testing the propeller for uniformity of weight along its length is shown in Fig. 14. Here one end of the propeller is held loosely in an opening and the whole propeller suspended with a spring balance at different given points along its length. The propeller is then reversed and suspended in the same way from corresponding points on the other end. If the weights balance on both ends of the propeller, the centrifugal stresses should be practically equal and the propeller run satisfactorily.

It is also quite important that the surface areas of both ends of the propeller should be equal. This can be easily tested by measuring the width of the blades at given points on each end and seeing how they compare. The joints of wooden propellers are frequently tested by revolving the propeller at from 5 to 10 per cent higher speed than that at which it will be run and then examining the joints carefully to be sure that none of them has started. These joints should not show glue, as the wooden layers should be solid together.

The propeller surface should be very smooth, particularly near the outer end where the speed is the greatest. When it is considered that the tips sometimes have a speed of 30,000 feet per minute, it may readily be seen how the surface affects the skin friction.

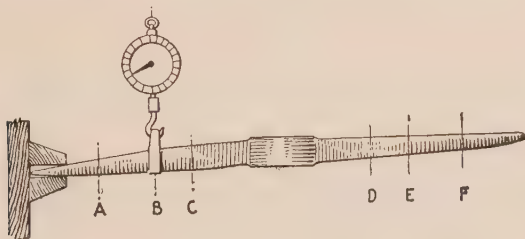


FIG. 14.—Testing uniformity of weight.

There are a great variety of propeller hub mountings, one of which is shown herewith in Fig. 15. This requires no explanation, as the methods of holding the propellers are clearly shown. It is very necessary that the propeller be mounted square and straight on the shaft and that it be securely fastened. This squareness can be tested in a similar manner to that already described for the straightness of the blades, by revolving it halfway and measuring the position of the leading edge or some other point on each blade. A propeller is sometimes thrown out of squareness by having the bolts tightened up too much on one side. Tighten them up gradually, going around the hub until all bolts have an even tension.

Wooden propellers should receive the best of care, as so much depends upon them and they are so easily affected by outside influences. They should be covered from the sun if the machine is to stand long in the open. Bags, or covers made from heavy cloth are slipped over the

blades and tied with draw strings. Propellers should never be stored in a damp place nor yet in a very dry place, as either condition affects the glue which holds the layers together. They should never be stored out of doors, on account of both sun and rain.

The best method of storing all propellers is to hang them in a vertical position on a strong peg which goes through the shaft hole. It is not a good plan to lean them up against a wall or to hang them in a horizontal position. The object is to avoid any stresses which will tend to get them out of shape in any way, as, unless they are symmetrical

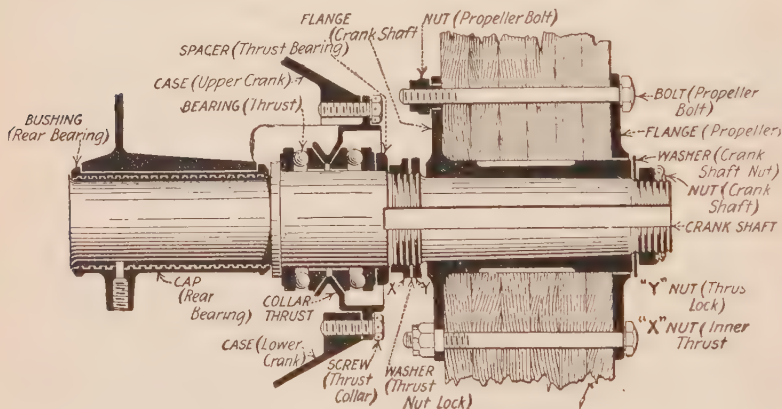


FIG. 15.—A typical one-piece propeller mounting.

and in good condition, they are not efficient. They are apt to vibrate or "flutter" badly, and this has a bad effect on the engine and its bearings.

Four-bladed propellers are seldom used and then mostly in cases where the pitch is comparatively large. There is, theoretically at least, more interference in the disturbance of the air where four blades are used. When one blade receives air which has already been set in motion by the blade preceding it, there is less reaction and consequently less efficiency.

Wooden propellers must be watched carefully to detect splinters, cracks, and other defects which might cause trouble. Bad landings usually damage a propeller, as the machine is very apt to nose down

and the propeller strikes the ground. Wooden propellers of flying boats and seaplanes are often nicked and chipped by the particles of spray which strike the blades as they are starting or landing. The high speed of the propeller makes the spray strike a much harder blow than might be imagined. The same is true when the machine is flown in a sandy country as the sand cuts the blades quite seriously at times.

Copper protection strips are often riveted over the edges of propellers at the ends, serving to protect the outer ends, which are most apt to be damaged. The only objection to these is that they sometimes tear loose and have been known to cut guy wires and even the fuselage in the case of a pusher-type machine. In some instances, protecting strips of canvas have been used for this purpose, being glued on the blades in the desired positions. These protect the blade fairly well and do less damage even if they loosen and fly off.

TESTS OF PROPELLERS

To test the pitch angle, the propeller is mounted on a shaft at right angles to a beam which is straight and true. Pick out some point on the propeller at any given distance from the center of the hub and, by means of the protractor as in Fig. 7, find the angle the propeller makes with the beam at this point. Lay out this angle on a large sheet of paper, as in Fig. 16, this being the chord of the pitch angle. The straight or base line must represent the circumference of the propeller at the face of the beam.

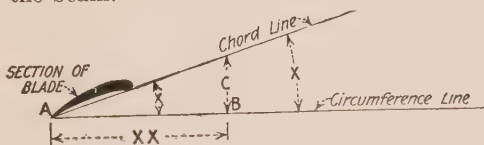


FIG. 16.—Laying out curve of propellers.

If this point is taken at 2 feet from the center, we have a circle 4 feet in diameter, or (4×3.1416) -12.5664 feet in circumference. Bring this down to any scale which is convenient, say, 2 inches to the foot, and lay off the horizontal line 25.135 inches. Then the distance from this point on the circumference line to the chord line is the pitch at this point. This should agree with the specified pitch of the propeller. An error of $\frac{1}{2}$ degree is permissible but more than this should be reported.

This test should be made at several points and the results carefully checked up. The surface area can be easily calculated by measuring the width at several given points; these measurements should be accurate within $\frac{1}{8}$ inch at any point.

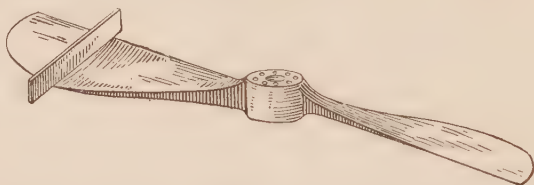


FIG. 17.—Testing curve of blade

The camber or curve of the blade can also be tested quite easily on the concave side by passing a straight-edge along the blade, as in Fig. 17, and noting the space at different points. On the convex side, this requires a set of templates which can be readily made from the drawings of the propeller.

INSPECTING METAL PROPELLERS BY ETCHING

The Boeing Air Transport Company has developed a method of inspecting metal propellers by etching.

The purpose of the etching operation is to remove a film of metal of minute thickness from the surface of the propellers and to reveal and magnify existing defects. The operations are as follows:

- (a) Immerse in, or swab with a caustic-soda solution.
- (b) Rinse with water.
- (c) Immerse in, or swab with a nitric-acid solution.
- (d) Rinse with hot water.
- (e) Inspect for cracks and defects.

The caustic-soda and nitric-acid solution will be made up as follows:

(a) *Caustic-soda Solution.*—To each gallon of water add 1 to 2 pounds of commercial caustic soda. This corresponds to 10 to 20 per cent aqueous solution.

(b) *Nitric-acid Solution.*—To each 5 gallons of water add 1 gallon of commercial nitric acid. This corresponds to a 20 per cent aqueous solution.

CAUTION: Wood, glass, or earthenware containers must be used for both the caustic-soda and nitric-acid solutions. In mixing the acid, *always pour the acid slowly into the water.* Rubber gloves should be worn at all times while working with these solutions.

SECTION VII

ENGINE AND PLANE ACCESSORIES

In order to give more complete information to the owner, pilot, mechanic, and others directly interested in the mechanism, whose functioning is so important, salient points concerning carbureters, magnetos, starters, landing gears, wheels, tires, brakes, floats, and parachutes, are given herewith. The source of information in each case is the manufacturer of the equipment mentioned.

AIRCRAFT LIGHTING

The Department of Commerce requires all aircraft flying later than $\frac{1}{2}$ hour after sunset, to display navigation or running lights. These lights must conform to the Air Commerce Regulations which are similar to nautical practice and are given in Sect. XIV. The navigation light shown in Fig. 1 meets these requirements. Side lights are designed for mounting on vertical surfaces and tail lights for mounting on a horizontal surface. When so mounted, the shielding permits the lights to be seen only through the angles specified (p. 627). These lights are

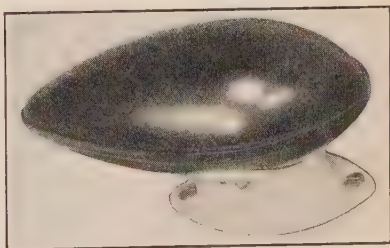


FIG. 1.—Navigation light for wing tip.

made with a substantial cast aluminum-alloy base and are easy to install. The shell is of celluloid and is red, green, or clear according to the position in which the lamp is to be mounted. It is easily removable for replacing lamp bulbs which are standard automobile headlight bulbs, 12-volt, 21 candlepower, and double contact.

As night flying is now very common, lighting equipment is standard on most planes. Nearly all aircraft manufacturers have standardized

on a 12-volt, two-wire system although some use 6-volt circuits and in some instance a single wire or grounded circuit is used where all metal parts are bonded for radio shielding. In such installations the bonding acts as a ground for the circuit. Navigation lights are also made in other styles and with lenses either of glass or celluloid. Sometimes 32 candlepower lamps are used.

In wiring for navigation lights a No. 18 B. & S. gage is the smallest that should be used. Smaller wires frequently overheat and cause trouble. It is also recommended that the insulation should not contain rubber, owing to its rapid deterioration and the difficulty of inspection when trouble occurs.

LANDING LIGHTS

Aircraft used in cross-country flying after dark are usually equipped with landing lights for use in emergency landing or when it is necessary to use a poorly lighted airport. Landing lights usually consist of a

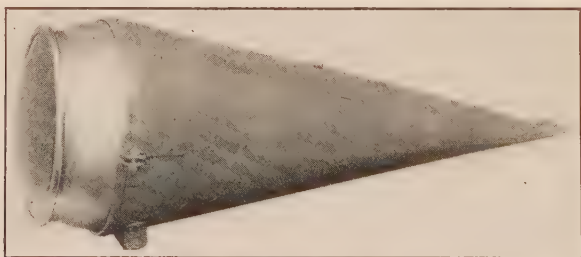


FIG. 2.—Typical landing light.

lens, a parabolic reflector, and a streamlined casing. These are mounted either at the wing tip or under the wing near the end. Some plane makers build the reflector directly into the wing and so dispense with the streamlining. A typical landing light is shown in Fig. 2.

The majority of landing lights use a 12-volt lamp with a mogul base, the lamps consuming about 35 amperes each per hour. Some use a smaller light with a 12-volt standard base and a lamp of 100 candlepower. Wire used for landing lights should not be smaller than No. 8 B. & S. gage, and a No. 6 wire should be used if the lights are likely to be in service for extended periods.

Parachute Landing Flare.—The parachute flare is a device designed to provide a pilot sufficient ground illumination to enable him to bring his plane safely to earth in event of a forced landing after dark. When something happens on board a plane at night which might require it to land, the pilot immediately needs illumination which will show him the location of a suitable landing place so that he may safely set his ship down. The Airways Parachute Flare, Type III (Fig. 3) or Wiley Flare, as it is commonly called, will, a few seconds after it is released, light up an area of about $1\frac{1}{4}$ miles in diameter from an altitude of 2,500 feet above the ground. The flare then floats slowly down, lighting up the ground more and more brilliantly as it descends. The flare lasts for about 3 minutes and burns with a candlepower between 300,000 and 400,000. It may safely be released at an altitude of 1,200 feet without danger to life or property beneath.

The flare is carried on a bracket inside the fuselage in an unused but reasonably accessible part of the plane, usually to the rear of the cockpits or cabin. A release cable connects the flare to an operating handle in a position convenient to the pilot.

The flare is cylindrical in shape, 25 inches long, $4\frac{1}{2}$ inches in diameter, and weighs 19 pounds. It consists of an illuminant and a parachute in a cylindrical sheet-metal casing which is strong enough to stand general handling. At the bottom of the casing is a cap that is retained by a spring steel band which is held in place by a releasing fork. When this releasing fork is pulled, the steel band flies away from the case, frees the bottom cap, and allows the illuminant to fall out, dragging the parachute after it. The parachute opens at about 50 feet below the plane and supports the illuminant. The jerk caused by the opening of the parachute operates a friction-igniting device which in turn sets off the illuminating mixture. This igniting device has been found to be more reliable, after extensive tests, than any other of its type or of any mechanical or electrical device tested. It is advisable when releasing a flare to have the nose of the plane pointed down-

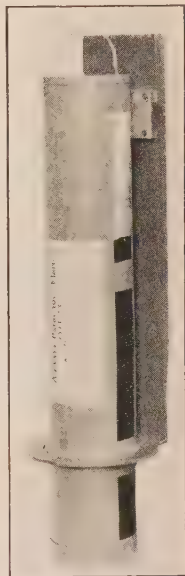


FIG. 3.—Wiley landing flare.

ward. Nosing up might cause the tail skid to catch the parachute as the flare travels backward from the plane.

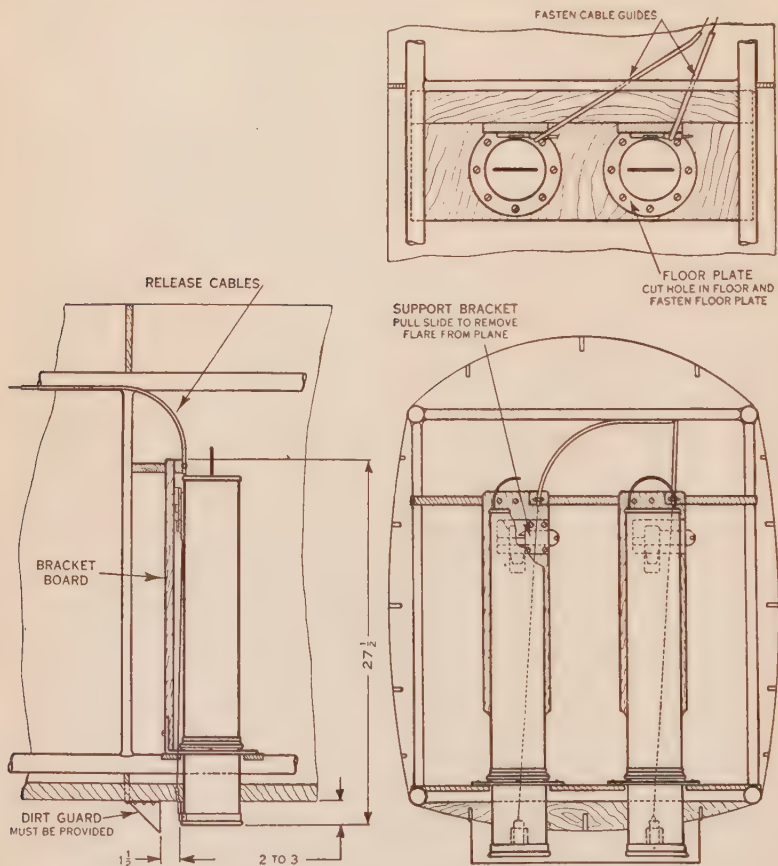


FIG. 4.—How the Wiley flare is mounted.

The method of mounting the flare is shown in Fig. 4. A mud or dirt guard, similar to that shown, should be installed to protect the end of the flare from accumulations that interfere with its proper release. A clearance of $1\frac{1}{2}$ inches should be maintained between the flare and

the guard to allow free action of the spring steel band. The bottom of the flare which projects below the plane should be wiped off with an oily rag at each inspection of the plane to remove any accumulations of dirt. About once a month the flare should be inspected, following the directions of the maker. It is also suggested that the flare be returned to the maker about once a year for thorough inspection. Two flares are generally installed, as shown.

HAND FUEL PUMP

Modern aircraft engines are equipped with power-fuel pumps as an integral part of the engine. An emergency hand-fuel pump, or "wobble pump," as it is usually called, is standard equipment on all Army and Navy planes and on many commercial ships. This pump is for use in case of the failure of the engine-driven pump, and it has proved to be of vital importance on many occasions. (See Fig. 5.)

This pump is mounted in the gasoline supply line at a point convenient to the pilot or mechanic, usually at the side of the fuselage. This pump is operated by an oscillating movement of the handle and is very efficient. The smallest pump of this type delivers more than a gallon of gasoline per minute when operated at the rate of one stroke per second. The larger models are proportionately faster.



FIG. 5.—Hand or "Wobble" pump.

STROMBERG CARBURETER

The carbureter plays such a vital part in the proper running of the present internal-combustion engine that it is well to understand its construction and operation. The Stromberg aircraft carbureter, shown in Fig. 16, is typical of modern carbureters even though details may differ to some extent. The instructions and suggestions follow:

Instructions for Setting Stromberg Aircraft Carbureters.—The determination of a fully correct carbureter setting and specification

involves the use of both a dynamometer setup and an airplane installation. With the dynamometer it should be possible to vary the speed and load as desired, and provision should be made for obtaining accurate readings of power, fuel consumption, and manifold vacuum. A carbureter setting is never considered as definitely correct until it has been thoroughly checked by airplane operation. It has usually been found that any discrepancy between the dynamometer and airplane performance occurs at the lower speeds. Where a dynamometer is not available, a propeller or torque stand can be used as a substitute, but the setting obtained should not be considered as final.

In obtaining a setting and specification, the first step is to determine the air capacity necessary for maximum power (or for power desired in case less than maximum is to be used), by selection of the power size venturi tube. Following this, the proper size metering jet should be ascertained. The idle adjustment should then be made at the lowest speeds, after which the idle intermediate range should be made correct. In exceptional cases it may be found necessary to change the accelerating well bore or the main jet air bleed from those initially furnished by the factory. These changes should not be made unless found to be necessary after the venturi and main jet size have been determined and fuel-consumption readings obtained over the whole running range.

A preliminary estimate of the venturi size may be made as follows:

With one carbureter feeding three or fewer cylinders, the area of the space around the discharge jet at the venturi throat should equal the piston displacement in cubic inches of one cylinder *times* the approximate maximum revolutions per minute *divided by* 133,000. With one carbureter feeding four or more cylinders, the area around the fuel discharge jet at the venturi throat should equal the piston displacement of all cylinders *times* the approximate maximum revolutions per minute *divided by* 480,000.

The average main metering jet orifice *diameter* is about 0.05 that of the venturi *diameter*.

In making the dynamometer setup, the same care should be taken to see that the installation is correctly made as for an airplane installation.

Determining Venturi Size.—The venturi tube should be large enough to give the engine full power but there is no advantage in having it larger than this. The restricting influence of the venturi tube on the air

passing through it may be measured by the suction existing in the manifold just above the carbureter with throttle full open. This is the manifold vacuum and should be carefully distinguished from the carbureter vacuum which is the vacuum existing at the throat of the venturi. With four or more cylinders pulling, maximum power will usually be obtained when the manifold vacuum is about $1\frac{3}{8}$ inches mercury or 15 inches water; with one carbureter feeding three cylinders, the maximum manifold suction for maximum power will be about $\frac{7}{8}$ inch mercury or $11\frac{1}{2}$ inches water. In making these measurements, it should be borne in mind that closing the throttle will greatly increase the manifold suction and a suction gage, if of the U-tube type, should be protected against emptying into the manifold when the throttle is so closed. While checking the venturi-tube size, a fuel-metering jet that is known to be adequately large should be used and the best mixture setting obtained with the altitude mixture control.

Determining Main Metering Jet Size.—Experience has shown that most satisfactory results are obtained when the engine is tested with the relative speeds and loads of propeller load; that is, starting from the contemplated normal speed at full load, the torque should be decreased as the square of the speed. With an engine of average mechanical efficiency, a uniform mixture of fuel and air would give the specific fuel consumption of the curve *A*, Fig. 6. Actually, advantage is taken of the fact that the mixture furnished at part throttle can be much leaner than that required for maximum power and curves of fuel consumption as *B* and *C* are obtained.

Different points on the mixture range are controlled by different elements of the carbureter as shown in Fig. 7. From about half speed up, the mixture proportion is controlled mainly by the size of the metering jet and, of course, by the altitude mixture control. Below half speed the mixture is controlled by the idling air bleed and at extreme idling by the setting of the idling discharge jet, according to the amount of its semicircular slot which shows above the throttle. On earlier models, the idling discharge jet was set at the factory and the idling adjustment accomplished by a taper needle valve working on the idling air bleed. On most of the later models, the idling air bleed is set by plugs drilled in different sizes and the lower idling adjustment accomplished by rotating the idling discharge jet to bring more or less of its semicircular opening above the throttle.

To find the proper size metering jet, reduce the jet size until the power begins to drop off with indications of a lean mixture. The proper size is the next larger one to that which showed the first slight drop in power. When the proper jet size is obtained, the engine will be fairly sensitive to the use of the altitude mixture control, beginning to show

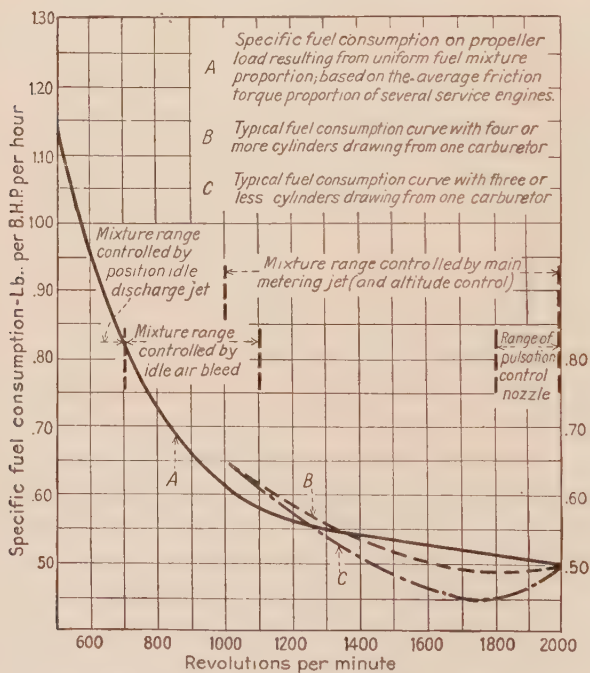


FIG. 6.—Typical fuel consumption curves.

lean and lose power with a small motion of the control lever and this can be used as a check.

The throttle or throttles should next be closed to give the minimum idling speed and the idling adjustment made. At this time care should be taken that the throttle openings are synchronized to the extent that the exhaust of the cylinders fed by the different carbureters are of approximately equal temperature. Care should also be taken that there

are no leaks in the intake manifold system either at the flange connections or at packed telescoping joints. A fairly rich idling mixture is usually desired. After the idling adjustment is made, the throttle should be opened to give an engine speed under propeller load about 100 r.p.m. less than half the normal maximum speed. This is just below the point the main discharge jet comes into action and the mixture is best controlled here by change of the idling air bleed, a smaller air bleeder making the mixture richer and a larger one leaner. The setting should be such as to give a fairly rich mixture as this is the speed usually used

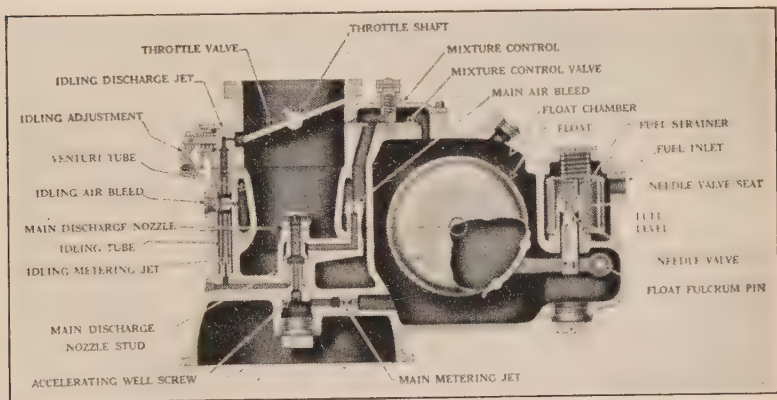


FIG. 7.—Diagram section showing general construction of Stromberg aircraft carburetors.

in the field for warming up the engine. On the variable air-bleed type of idling adjustment the air-bleed size is not fixed and the action in this range will have to be set as a compromise with the action at minimum idling speed. With the normal type accelerating well nozzle, change in the idling adjustment or idling air bleed should not affect the mixture range very far above half engine speed.

When three or fewer cylinders draw from one carburetor barrel, there are intervals of time during which no intake valves are open, resulting in strongly marked pulsations of suction. Under these conditions the mixture tends to be richer at wide-open throttle and full speed than when the throttle is partly closed as the closed throttle somewhat dampens the effect of the pulsations as transmitted to the carburetor jets. A mixture

curve, therefore, tends to differ from the curve given by the same carbureter on a four-cylinder engine, in that it grows perceptibly rich at full throttle, as shown in Fig. 6. As a means of regulating this amount of richness, the pulsation control accelerating well nozzle is used. Advantage is thus taken of the fact that at wide-open throttle the flow through the idling system reverses, and instead of fuel going through the idling nozzle as at low speeds, air is drawn back through the idling air bleed and through the idling metering jet into the main jet system. By using a reduced opening in the pulsation control accelerating well nozzle, this action of air flowing in the jet is made to give a leaner mixture than when the air does not so flow, the extent of leanness depending upon the amount the pulsation control nozzle is reduced in size.

When the pulsation control nozzle is used, a metering jet size to give the correct mixture from half speed up to within 100 r.p.m. of full load should be determined. At full load the desired mixture should be obtained by selection of the proper size pulsation control accelerating well nozzle. The low-speed idling adjustment and idling air-bleed adjustment should then be made as described above. A very considerable change in the size of the idling air bleed may have some slight effect upon the pulsation control nozzle size necessary.

Effect of Changing Accelerating Well Bore.—It may sometimes occur that when a considerably larger venturi is placed in the carbureter than that which was sent from the factory, and the proper main metering jet size determined for full speed, as the speed is decreased 400 to 600 r.p.m., the mixture becomes rich. This may well be shown by the fact that the mixture can be made much leaner by use of the altitude mixture control without affecting the engine operation. This is an indication that the bore of the accelerating well is too small and should be enlarged about in the same proportion as was the venturi area. It will be noted that for structural reasons the fuel passage in the main discharge system is made in two parts and the upper bore is the accelerating well bore. Enlarging the accelerating well bore will permit the use of a smaller metering jet and will bring the upper half of the speed range more nearly uniform as to mixture.

Effect of Changing the Main Air Bleed.—In general, decreasing the size of the main air bleed has the same effect as enlarging the accelerating well bore but the action is much less pronounced and such large changes

are necessary that it is preferable to work with the accelerating well bore.

Installation of Carbureter.—There are many factors involved in proper carbureter operation in service which cannot be cared for in the carbureter design alone. A recognition of the requirements regarding tanks, fuel lines, freezing in the manifolds above the carbureters, and the effect of rapid acceleration, including catapulting, must be had if the carbureter installation in an airplane is to be successful. The tanks and fuel lines must be so located that there is no tendency for an air lock to form between the tanks and the carbureter and obstruct the fuel flow. Figure 8 shows how a seemingly simple installation can contain the factors necessary for the formation of an air lock which could prevent the flow of any fuel from the tank to the carbureter.

As is well known, the vaporizing of fuel is only accomplished through the taking up by the fuel of a considerable quantity of heat. This heat is taken from the space immediately above the carbureter. Unless heat is supplied to this space, the temperature drops to a very low value and, besides the interference with vaporization, ice will form under certain atmospheric conditions. This ice formation constitutes a serious danger. The manifolds should be well heated, particularly above the carbureter and preferably throughout their length. Hot water, exhaust gas, or oil may be used for this purpose. It is often beneficial, especially for winter or cold weather operation and where the inlet manifolds of the engine are of excessive length, to heat the inlet air passing to the carbureter.

Rapid airplane accelerations, with the consequent fuel displacements and changes of level, are often greater than that of gravity and this is particularly true in the case of catapulting. The carbureters are so designed that even with these changes of level, fuel will continue to flow from the metering jets at the instant of acceleration. To continue

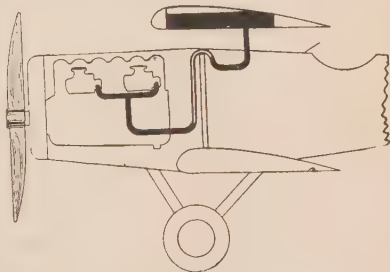


FIG. 8.—Showing how vapor lock in fuel line can prevent flow of fuel from tank. Note that height of fuel column at left just balances that of fuel column at right, giving equilibrium without flow.

functioning, however, the fuel supply to the carbureters must continue as normally and for this to be accomplished the locations of the tanks, fuel lines, and carbureter must be so related that, with these conditions existing, the natural tendency of flow is to the carbureter and not away from it.

Installing on Engine.—Before mounting the carbureter on the engine it should be thoroughly checked to see that all screws, plugs, bolts, et cetera, are “safetied” with lock washers, cotter keys or safety wire. Make certain that the proper manifold flange gaskets are in place.

The throttle discs should be examined closely to see that they fit securely in the barrels and if there is more than one disc to a carbureter a careful check should be made to see that they are perfectly synchronized. The action of the engine at minimum speeds depends to a large extent upon the synchronization of the throttles. The discs should never be hammered as this prevents any possibility of securing a fit.

The flanges should be pulled tightly together.

If more than one carbureter is used per engine, the throttles of the carbureter should be carefully synchronized with each other. This is usually done by adjusting the throttles so that they are in exactly the same relative position at extreme closed throttle, making certain that the throttle stop has not interfered with the seating of the discs in the barrels.

For an airplane installation the cockpit control rods should then be connected to the corresponding levers on the carbureters. After connection these should be carefully gone over to see that the full limit of travel is obtained for each lever and that the levers move in the proper direction as indicated in the cockpit. The fuel and drain lines before being connected to the carbureter should be flushed out to make certain that the flow is free.

Starting Engine.—Before starting the engine for the first time, it is better to set the idling adjustments well toward the “rich” position to make certain that the engine secures sufficient fuel.

To start the engine, close the throttle and turn the propeller in the forward or running direction through three or four complete revolutions. Open throttle slightly and try with hand-starting magneto or, if the engine is not provided with this magneto, “pull through” by hand in the usual manner. If the engine does not start, close the throttle and turn the propeller again by hand through one or two revolutions. Try

the hand magneto. The wells in these carbureters are of the self-priming type and there is a possibility, especially in warm weather, of getting the engine in the so-called "loaded up" condition. Therefore, do not continue to turn the engine forward with the throttle closed if it has failed to start but open the throttle and turn the engine backward for three or four revolutions. Then close the throttle to the starting position, turn forward once or twice and try. If at any time it is desired not to use the self-priming action of the carbureter, this can be done by opening the throttle about a third of its total movement. For starting with an electric starter, the throttle should be closed until the starter has turned the engine over through three or four revolutions, then work throttle by alternately opening to about mid position and closing, until engine starts.

After the engine has started, it should be allowed to become completely "warmed up." If this is not done, any adjustments made will be useless. When the engine is thoroughly warm the minimum speed operation should be made satisfactory. This is done by means of the idling adjustments and the throttle stop screws which regulate the minimum throttle opening. It will generally be found that the best operation is obtained with an idling mixture amply rich. Care should be taken though to see that it is not too rich so that the engine "lopes" or "loads up" when idled for a long period of time. A good indication of a too rich idling mixture is the operation of the cylinders on an eight-stroke cycle; that is, they will fire only once for every two openings of the exhaust valve.

The next step is to try the engine operation over the whole range by gradually opening the throttle so that the engine speed increases by increments of about 100 r.p.m. On carbureters with an adjustable air bleed idle, it may sometimes be found that there is a slight "flat spot" at around 700-900 r.p.m. This can usually be remedied by use of the idling adjustments. If this is done, the engine should be immediately brought back to idling speed to see that the operation here is still satisfactory.

The acceleration should then be tried by rapidly opening the throttle from different engine speeds over the range from extreme idling to 600 or 700 r.p.m.

Test the operation of the mixture control by opening the throttle and allowing the engine to come to full speed and then moving the control

slowly in the "lean" direction. If the engine speed is greatly reduced, the control is functioning properly.

Routine Inspection in Airplane.—The carbureter strainer should be inspected after every flight to see that it is not clogged at any place and to clean out the accumulated foreign matter. In addition, a regular inspection should be made of the feed and drain lines to see that they have a free flow. The controls should be thoroughly checked to see that they do not stick and that there is no lost motion. The carbureter should be examined, making certain that all safety wires, cotter keys, et cetera, are in place and that no parts have become loose. Then "run up" the engine as given under "Starting Engine."

Complete Inspection and Overhaul.—This should be done in any case where the exact condition of the carbureter is not known, where the carbureter has been in service for a long period of time, or where the carbureter action is known to be bad.

The carbureter should be completely disassembled, removing all parts including the float mechanism, but excepting the throttle valves whose condition can be observed in place.¹ It will be found that tapping the brass plugs lightly with a softwood or horsehide mallet will aid greatly in their removal from the aluminum body. Care should be taken that the carbureter is not injured. Wash the carbureter body and parts in gasoline or its equivalent, using an air hose to blow through the passages and clean the different parts. Then examine *all* passages to see that they are clean. To do this the carbureter must be held to a good light or a flash light used. A good method of making this examination which insures that no passages will be overlooked is to follow the flow of the fuel from the float chamber through the drilled holes, metering jets, wells and well tubes to both the main and idling discharges. Check the air-bleed passages to see that they are clean. Check the metering jet and air-bleed plug sizes against the sizes marked on the aluminum setting plate. See that the idling adjustments are correctly in place and that the throttle valves fit snugly in the barrels and are

¹ Also the idle discharge jets, on carbureters which have the air bleed idle adjustment, should not be disturbed because of the accuracy of adjustment required in replacement. If, however, these idle discharge jets have been accidentally displaced the correct setting will be approximated when one-fourth of the half-moon opening shows above the throttle valve (on manifold side), when same is entirely closed.

well synchronized. The later double models with parallel throttle shafts geared together have a means of adjustment to obtain accurate synchronization. One of the pair of gear sectors is not pinned to the shaft, but is clamped by means of a bolt and nut. Loosening this nut will allow the gear sector to be turned on the shaft and an adjustment secured. This adjustment should be carefully made, using a thin tissue paper of not over 0.003-inch thickness to check the fit between the throttle valve and the barrel. Move the float up and down to see that its movement is entirely free. Check the movement and condition of the mixture control valve. Thoroughly examine and check all the parts for wear or irregularities. Replace by new parts where necessary. Reassemble the lower half of the carbureter using the instruction sheets furnished for the individual model.

Before installing the needle valve and seat, they should be checked for leakage by holding the needle point upward with the seat in place and filling the small space above the needle with gasoline. If leakage is evident, the needle valve should be lapped in with crocus powder. If a good seat is not obtained after lapping, a new needle valve and seat should be used.

It has been found in service that brass plugs screwed into aluminum have a tendency to stick or hold if they have been in place for a long period of time. This trouble can be obviated by the application of a thin coating of graphite oil paste to the threads of the plugs or other parts before screwing into place. The paste is made by mixing powdered graphite and castor oil together to give a compound with a consistency such that it will just flow. Only a thin coating should be applied and care must be taken to avoid forcing any of the mixture into the carbureter.

After assembling the lower half of the carbureter, the float level should be checked and this is done most easily by holding the lower half rigidly in a level position with a vise or other means, admitting fuel under a 4 or 5 foot gravity head through the regular inlet connection and measuring the distance from the level in the float chamber to the parting surface. This measurement can be made either by means of a scale between the surfaces directly or by use of a glass tube or gage glass connected to the float chamber. The use of a gage glass is the preferred method, particularly where a number of carbureters are to be checked. In case of an incorrect fuel level, adjustment should be made by changing the thick-

ness of gaskets under the float-needle seat. If the float needle is between the float and the pivot, increasing the gasket thickness will raise the level and *vice versa*. If, however, the pivot is between the float and the needle, the action is reversed and increasing the gasket thickness will lower the level. The amount of change varies with different lengths of float brackets but a change of $\frac{1}{64}$ inch in gasket thickness will change the level approximately $\frac{5}{64}$ inch. Great care should be exercised in removing and replacing the needle seat, both to see that the gaskets are not misplaced or lost and that the needle-valve seat is screwed tightly in place. A broad screwdriver is required for this operation. After the correct level has been obtained, the carbureter should be allowed to stand, with the fuel line connected, for 20 or 30 minutes and the fuel level measured again. This is a check for a "creeping level." If the level has risen, drain the carbureter, remove the needle valve and seat, and follow the procedure given on page 331 for a leaky valve.

Reassemble the complete carbureter, taking care to see that all gaskets are in place, and that all loose parts are "safetied."

Bench Inspection.—When a carbureter is being changed from one engine to another or in any case where the condition is known to be good and it is desired merely to make a simple inspection to obtain that factor of safety necessary in all aircraft work, the following procedure should be gone through:

The carbureter halves should be separated by parting at the joining surface. All plugs, screws, etc., at the ends of fuel passages should be removed. All fuel passages should then be examined as given in detail under "Complete Inspection and Overhaul." Check the setting against that marked on the setting plate. See that the throttle valves fit the barrels and that the float movement is free. Test the mixture control valve for proper assembly and movement. Examine all moving parts for wear or irregularities. Clean any dirty parts and then reassemble the carbureter, taking the necessary precautions to see that all gaskets are in place and all loose parts "safetied."

These are given as being typical instructions for a standard carbureter. While construction details vary the principles will apply to other carbureters.

The Float Level.—The effect of the float level is so great on some of the operating characteristics of the carbureter that its proper location is of the utmost importance. A too high level gives flooding and conse-

quent fire hazard, wastage of fuel, etc., If too low, there may be poor operation of the engine from 600 to 1200 r.p.m. with possible "backfiring" and, in addition, poor or no acceleration when the throttle is suddenly opened. The level should be exactly correct, as stamped on the specification tag on the carbureter, with the fuel and operating head used in actual service and there should be no "creeping" of the level.

SCINTILLA AIRCRAFT MAGNETO

Magneto ignition is almost universal on aircraft engines and as the Scintilla magneto is to be found on a large percentage of American-built engines, it will be used in describing the care of magnetos on aircraft engines. The construction of the Scintilla magneto, however, differs materially from other types, as the former system is reversed by having the magnets revolve. These magnets have either two or four poles and the pole extremities are laminated, the laminations being held in place by an end plate which carries the breaker cam. The rotation of the magnet produces reversals of magnetic flux through the core of the coil. The parts are shown in Fig. 9.

In disassembling the magneto for either inspection or repair, it is advisable to have tools designed for the purpose and to use extreme care both in taking the magneto apart and in preventing loss or mislaying of parts. One of the first steps is thorough cleaning of parts. All parts may be washed in gasoline and dried with compressed air except the coil. Wipe all pieces of dielectric material with oil-saturated cloth after cleaning.

There are, however, several precautions to be observed in drying off the parts. The number discs in the distributor blocks and those on the top of the main cover must not be exposed to full air pressure. Hold them at a safe distance or else allow them to dry in the open air. Great care should be taken that the felt strips in the magneto housing, the main cover, the breaker cover, and the front end plate are not loosened or torn out by the air pressure. Oil all felt strips after cleaning.

It is imperative that the cage and bearing assembly of each bearing be held so that they cannot spin when using air for cleaning. This will prevent throwing out the balls and making it necessary to obtain a new cage and ball assembly to complete the bearing for reassembly.

Keep rotating magnet clean inside and out. Do not lay it near small screws, nuts, or metal chips, etc. Its construction is such that

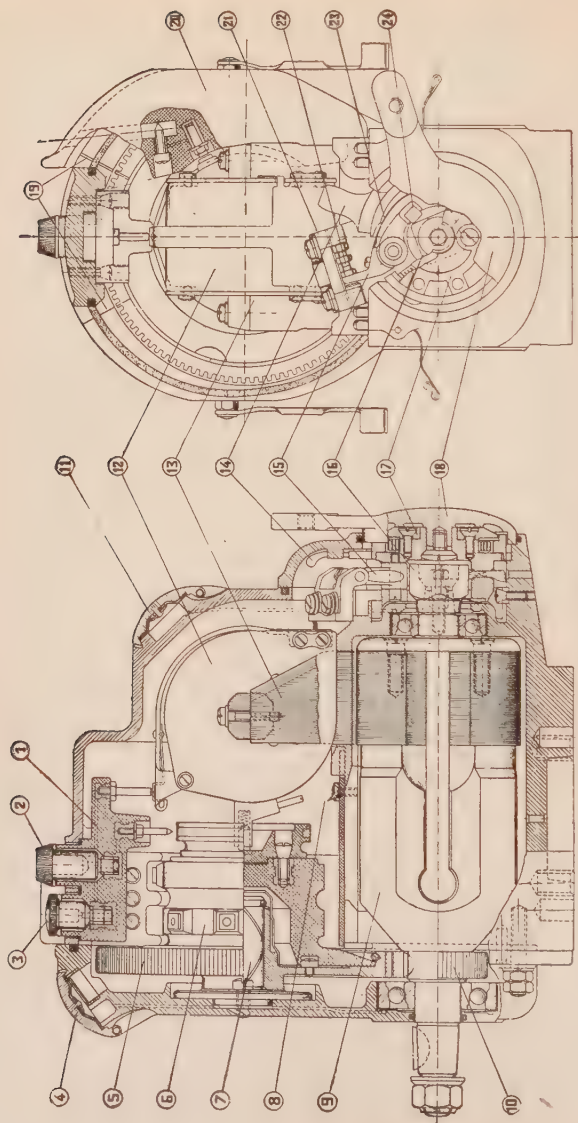


FIG. 9.—Sectional Drawing of Scintilla Aircraft Magneto.

1, Booster and ground connection block; 2, Fastening screw for booster wire; 3, Fastening screw for ground wire; 4, Front oil hole and timing window cover; 5, Distributor gear; 6, Distributor gear; 7, Distributor cylinder; 8, Safety gap; 9, Rotating magnet; 10, Small distributor gear; 11, Rear oil hole cover; 12, Coil; 13, Laminated pole shoes; 14, Bayonet lock latch; 15, Contact breaker lever; 16, Cam; 17, Dog plate; 18, End cover with advance lever; 19, Timing marks; 20, Distributor block; 21, Insulated support; 22, Contact points; 23, Breaker lever main spring; 24, Cam follower.

any foreign material adhering to it will result in serious injury to the magneto. After cleaning rotating magnet, grease thoroughly to prevent rust.

Inspection.—It is anticipated that the inspection and repair of the Scintilla aircraft magneto will offer very little, if any, difficulty to the average ignition mechanic, who has had experience with other types of magnetos. Therefore, this section on inspection and repair will embody only such instructions as are deemed necessary to cover certain features which are characteristic of the Scintilla.

Magneto Housing.—The breaker stop and the safety-gap ground plate must be tight and their fastening screws locked. Have $\frac{3}{8}$ -16 cap-screw hold-down holes clean and threads straight. Lap base just enough to see that its surface is smooth. It is imperative that the oil lead to back bearing be open and clean. Flush with a good grade of light oil after cleaning.

Front End Plate.—Lift oil wick and spring out of distributor gear axle. Clean oil leads to axle and front end bearing and flush with a good grade of light oil. Replace oil wick in distributor gear axle. See that fastening screws for distributor gear axle are tight and locked to the outside surface of the front-end plate.

Examine large distributor gear to see that there are no burrs on teeth of gear. Replace gear, taking care to hold wick down until covered by gear bearing. Replace spacing washers and spring ring. Try end play of gear on shaft. If not less than 0.005 inch or more than 0.008 inch, it is satisfactory. Test dog screw. It must be tight and locked to the large distributor gear.

Replace paper-spacing washer and distributor cylinder. Replace spring ring. Total thickness of spacing washer should be such that distributor cylinder will be held tightly against distributor gear. Force spring ring into its groove throughout its length.

Breaker Assembly.—Replace end cover with advance lever on breaker assembly. Place assembly in position in magneto housing and note that it functions as follows:

The bayonet lock latch, when released, should snap into position and the breaker will spring over to full advance. Remove breaker and lay aside for adjustment during final assembly.

Main Cover.—Clean oil lead to back bearing thoroughly. Examine booster and ground connection block in top of main cover, especially

around the terminal marked "H," as any small cracks in the material would ground the booster current.

Coil.—Note that secondary brush holder is solid with the coil. It is of vital importance that the spring contacts on the primary bridge be in good condition. The rear spring bears against the face of the insulated support on top of the breaker cage, while the front spring located above the coil, makes contact with the ground contact stud.

Distributor Blocks.—Examine electrodes. Be sure that they are screwed tight into the distributor block. Loose number discs must be glued with a water- and oil-proof glue. After glue is dry, apply white shellac as an added precaution.

Rotating Magnet Assembly.—Check cam fastening screw. Note condition of ball bearings. It will be noticed that the cage and balls of the front bearing are a loose part on the AG 12-D rotating magnet, while on the AG 8-D and AG 9-D rotating magnets they stay on the inner race. This allows the balls to clear the large distributor gear during the assembly of the AG 12-D. All types of rotating magnets carry the cage and balls for the rear bearing on the inner race.

Examine laminated pole end of magnet for any signs of rubbing due to foreign material lodging between laminated ends of magnet and pole shoes. The clearance between laminated poles and pole shoes is 0.002 inch. This explains the necessity of keeping them clean and free from any foreign material.

Final Assembly.—It is presumed that as near as possible the mechanic will use the original parts of the magneto for the reassembly. While Scintilla parts are readily interchangeable in each type of magneto and for a given rotation will function in another magneto of the same rotation, much time and effort will be saved by using the same rotating magnet, magneto housing, and front end plate in the reassembly.

The end play and bearing fit of the rotor in the magneto in most instances will be found correct. The rotating magnet was taken as the last subassembly for inspection so that while it was cleaned up it could be installed in the magneto housing immediately.

1. Have magneto housing clean and ready to receive rotating magnet.
2. Take up the rotating magnet and fill the rear ball cage with good light grease. Grease magnet all over, leaving a film of grease to prevent rust.

3. Recharge rotating magnet, clean off metal particles that may be adhering to poles and place in housing at once. The magnet is easily replaced by turning it until a flat surface is at the top, then push in place. Now turn rotating magnet right or left 45 degrees or until the space between the top of the pole shoes is filled by one of the poles of the magnet. This is the neutral position for the rotating magnet and it should always be left in this position unless there is a keeper across the pole-shoe extensions.

4. Fill cage and ball assembly for front bearings with the light grease mentioned above, put it on over the shaft and place it on the inner race. Note: If the magneto is an AG 12-D the cage and ball assembly must be placed in outer race in front end plate and assembled with it.

5. Observe the arrow on top of the main cover to find direction of rotation for which internal timing was originally set. If arrow points anticlockwise, as viewed from the drive end of the magnet, match all timing marks "G." If arrow points clockwise, match all timing marks "D." Suppose the magneto to be assembled is an anticlockwise or left-hand rotation:

6. Turn rotating magnet until the marked tooth on back of small distributor gear is up in view so that it may be matched with the marked tooth on the large distributor gear.

7. Take up front end plate and put in on overdrive end shaft until edges of gears are about to touch, holding the plate in one hand and guide the mark on the large distributor gear by turning the distributor cylinder with the other hand. When the marked tooth on the small gear and the marked tooth on the large distributor gear are matched, push the front end plate up against the magneto housing and secure by means of the two screws and studs provided.

8. Test rotating magnet for end play. There should be none. The bearings should be just tight enough that when the magnet is turned about 30 degrees from the neutral position it will return to the neutral position by its own magnetic pull.

9. Replace breaker assembly for final setting. Set contact points so that their maximum opening will be 0.012 inch. The small gage on the Scintilla contact point wrench may be used for this purpose.

When contact points are set at 0.012 for maximum opening the clearance between back of breaker arm and face of fiber stop should be from 0.002 to 0.010 inch.

Check clearance on each cam lobe. The cam must run true within 0.0005 inch.

10. The internal timing of the magneto must now be checked. Turn rotating magnet until No. 1 on large distributor gear is in line with the mark in the timing window; the supplemental timing marks, located on inside edges of large distributor gear and the front end plate, should also be in line at this time.

By slowly rocking rotating magnet with the breaker in full advance position, the points should be just on the instant of opening as No. 1 and its mark and the supplemental timing marks come in line with each other. Hold rotating magnet with timing marks in line and with one hand place the right distributor block in position. When magneto is correctly timed, the No. 1 electrode will coincide with a segment on the distributor cylinder.

11. Remove breaker assembly; this permits an easier installation of the coil.

12. Place coil between pole-shoe extremities. This is best accomplished by sliding coil in from the back and moving it forward into position. The coil fits tight and often causes the pole-shoe extensions to shear off a very thin piece of the fiber side plate. Take every precaution that none of this fiber gets in between the ends of the core of the coil and the ends of the pole-shoe extensions. Secure coil with a fastening screw in each end of the core.

13. Replace breaker assembly. Spin magneto; if properly assembled and timed a good snappy blue spark will jump across the safety gap. The safety gap should be not less than $\frac{3}{8}$ or more than $\frac{1}{2}$ inch.

14. Put main cover in place. Take great care that it fits housing. Have bottom edges of main cover smooth. It is important that cover fits housing accurately since the top extension of cover acts as a stop for the distributor blocks while the housing supports them at their lower end. Any serious misalignment would result in injury to electrodes in the distributor blocks and segments in the distributor cylinder. Fasten main cover to housing with two long screws provided.

15. Replace breaker cover. Fasten spring clamps and safety.

16. Replace distributor blocks. Match them up with the number discs on the sides of the top of the main cover. Fasten distributor block spring clamps in place and safety. This completes the final assembly.

Testing Magneto. *Mechanical.*—Where the equipment is available, the magneto should be tested immediately after final assembly is completed. Its operation during the bench test gives the experienced mechanic an accurate knowledge of the mechanical and electrical condition of the magneto.

Mount magneto on test bench and remove breaker assembly. Run magneto up to about 1,000 r.p.m. and listen carefully to its running. The period of any unusual or irregular noise as compared with drive shaft speed, will give a good indication as to its origin.

While listening to the magneto, note the hum of the gears. When running properly they will have a consistent hum. The pitch of this hum will vary slightly for different magnetos, but will be consistent for a given magneto when gears are running properly.

When there is foreign material imbedded in the face of the large gear, it will cause an audible click or knock each time it is turned against the small distributor gear. If it is in the face of the small distributor gear, the period of the knock will be that of the drive-shaft rotation since the small gear is keyed to the drive shaft.

Should the gears run irregularly and tend to chatter, there is excessive play either in the distributor gear axle bearing or between the teeth of the gears.

If there is a knock in the magneto housing, it is usually caused by the laminated poles hitting the pole shoes. Most trouble in the magneto housing is caused by small metal parts, such as filings, chips, broken lock washers, etc., that are picked up while the rotating magnet is laying on the bench. They are thrown out by centrifugal force and cause serious damage to the rotating magnet and pole shoes.

Unusual tightness or rubbing in housing may be noticed by the magneto running exceptionally warm during test. If the condition is bad, it will be noticed by an irregular and unusually hard turning, when the drive shaft is turned by hand prior to the test run.

Electrical.—Replace breaker assembly and wire up distributor blocks to spark gap, which should be of the three-electrodes type in order to obtain good and consistent results for testing. The third electrode is a static point located so that it meets the live point at an angle of 90 degrees and is set with an air gap of about 0.002 inch between static point and live point.

The live point is the one connected to the distributor block by the high-tension cable.

The gap between the live point and grounded point is to be 7 mm. ($\frac{9}{32}$ in.). Keep all points sharp and clean to obtain best results.

Run magneto for about 10 minutes at a speed of 900 to 1,000 r.p.m. Observe points at start of test. Should they be excessively, remove breaker and clean them thoroughly. Have points dry and free from grease before replacing breaker. After 10 minutes at above speeds, run magneto up to 2,800 r.p.m. and maintain this speed for at least 5 minutes.

Observe the contact points. There should be very little sparking at points when they are clean and seat properly on their contact area.

Test primary grounding circuit at this stage of the test with a piece of wire. Put one end in the hole in fastening screw for ground wire and touch the other end to magneto body or frame of test stand. The spark across the gap should cease the instant the free end of grounding wire is touched to magneto or frame of test stand. The next running speed should be not less than 3,500 r.p.m. while 4,000 r.p.m. is desirable. Maintain this speed for at least 10 minutes.

Observe spark closely. A consistent miss can readily be detected. A slight scattering miss will be detected by a momentary break in the spark flame between the electrodes. A magneto, the internal timing and assembly of which is correct, will regularly fire across a 7 mm. ($\frac{9}{32}$ in.) air gap at 4,000 r.p.m.

Observe contact points. They should run practically free from arcing by the time the test has progressed thus far. The next test, after the high-speed test, is to obtain the coming-in speeds. The coming-in speed is the lowest speed at which the magneto will come in and fire consistently across the 7 millimeter air gap.

The maximum coming-in speed allowed for full advance is 120 r.p.m. while that for full retard is 240 r.p.m.

Coming-in speeds higher than those just given would indicate a magneto of low electrical efficiency. This may be due to improper internal timing or to the rotor having lost some of its magnetism through improper handling after being recharged or by spinning the rotating magnet without a keeper across the pole shoe extensions.

The booster starting circuit should be tested after the finish of the running tests. Use a hand magneto or vibrating high-tension coil as the source of high tension current. Connect high-tension booster current cable to terminal marked "H." Rotate magneto by hand.

Start with No. 1 in the timing window and observe that a spark jumps all gaps in the correct serial order as given by numbers on distributor blocks. Bear in mind that because the booster segments trail the service segment of the distributor cylinder, the booster spark will occur late, for example, when No. 1 shows in the timing window, the booster current will jump No. 12 gap. The same principle applies to the eight- and nine-cylinder magnetos.

A deviation from this serial order or no spark at all across gap indicates that the booster circuit is not correct. Examine parts for fine cracks or burnt spots indicating a short-circuit of the booster current.

Installing the Magneto on and Timing It to the Engine.—Make sure that the magneto shaft half of the drive coupling is seated and keyed on taper of drive shaft and then locked by nut and washer and safetied with a cotter pin. Spin magneto and note that drive shaft half of coupling runs true.

Inspect magneto base. See that the $\frac{3}{8}$ -16 threads in the hold-down holes have not been stripped or that the start of the thread has not been closed, thus having a tendency to cause capscREW to cross threads. When necessary, clear up threads with a $\frac{3}{8}$ -16 tap and then clean holes thoroughly.

Note dowel-pin holes. They should fit pins very snugly but not so tight as to cause difficulty in getting magneto down on surface of its support. See that the base of the magneto is smooth and makes good contact with the bracket surface.

Having made use of the above instructions and any other information that the mechanic has found to be useful from previous installations of this nature, the magneto is ready to be secured.

It is imperative that the length of the $\frac{3}{8}$ -16 capscREWS be correct. When in doubt as to correct length, it can best be obtained by direct measurement. Making allowance for the thickness of the washer used on the screw, the length must be such that when the screw is tight, it will not have less than $\frac{3}{16}$ or more than $\frac{1}{2}$ inch of its threaded length in the $\frac{3}{8}$ -16 hole in the base of the magneto. When the correct length is established draw the screws up tight and safety.

Timing.—Turn engine slowly as piston in cylinder 1 comes up on compression. Stop when the full advance position for the ignition, as given by the engine manufacturer, is reached. This point is given in degrees before top center (B.T.C.) and is marked on the timing disc

to be used with the engine. At this point the magneto is to be coupled to the engine, the following instructions having been very carefully noted and followed.

The No. 1 on the large distributor gear can be seen through the timing window located under the front oil-hole cover. When this No. 1 is in line with the white mark at the top of the timing window it indicates that the contact points are at the instant of opening with the breaker fully advanced and the No. 1 electrode on the distributor block is registering with the proper segment on the distributor cylinder.

Some installations do not permit of this window being used. In such cases the supplemental timing marks must be used. They are located on the inside surface of the large distributor gear and the front end plate and are so arranged that when they coincide with one another the contact points are at the instant of opening.

Fasten the spark plug cables to the distributor blocks. The numbers on the distributor blocks show the serial firing order of the magneto. The numbers on the top of the main cover are for the purpose of locating the right and left distributor blocks to their respective sides.

Observe that each magneto is wired to its proper set of wires as given by the engine manufacturer and that the wires lead from the magneto so that No. 1 on the distributor block goes to No. 1 on first cylinder in the firing order of the engine, while No. 2 on the distributor block goes to the second cylinder in the firing order of the engine; No. 3 on the distributor block goes to the third cylinder in the firing order of the engine, etc., until all cylinders have been wired in their proper firing order. Clamp distributor blocks in place.

The letter "H" marks the terminal to which the booster wire is to be connected. The letter "P" marks the terminal to which the ground or short-circuiting wire from the magneto switch is to be connected. The arrow indicates direction of rotation of the magneto when viewed from the drive end.

Tighten and lock the drive coupling. The advance lever linkage is to be connected to the advance lever on the magneto, special attention being given that full advance and retard are obtained when the spark lever in the cockpit is moved to its full advance and retard positions.

Special Instructions. *Changing Direction of Rotation.*—Disassemble magneto. Pull the cam and observe the small *D* and *G* stenciled on the face of the breaker end shaft. Assuming that this is to be a change of

rotation from anticlockwise to clockwise, remove Woodruff key from keyway marked *G* and replace in the one marked *D*. Replace cam and pull cam fastening screw up tight.

Remove distributor cylinder and then the large distributor gear. Remove small dog screw from *G* (within the circle) and replace in threaded hole marked *D*. Lock end of dog screw in face of distributor gear.

Note that *G* (without a circle around it) is to be used only when the magneto is for anticlockwise rotation *and has no booster connection*.

Remove the timing window and the supplemental timing marks on the inside surface of the front end plate. Replace large distributor gear and distributor cylinder. The distributor cylinder is now in the correct position for right hand rotation.

Observe that the collector ring for booster current has a *D* and *G* on its face, located 180 degrees from each other. There is a mark on the inside face of the distributor cylinder with which either the *D* or *G* must line up, depending upon the direction of rotation.

Remove collector ring for booster current and turn it so that *D* is in line with the mark on the inside face of distributor cylinder. Replace and fasten collector ring for booster current to distributor cylinder with fastening screws provided for it. .

Remove end cover with advance lever from breaker assembly. Unscrew dog plate fastening screws and remove dog plate. Now carefully lift the bayonet lock latch and spring off breaker cage. Remove the bayonet lock spring from the bayonet lock latch, turn it over and put it back in place. This is done in order that the lock spring may hold the breaker assembly in full advance.

The contact breaker lever axle and breaker lever are to be removed. This permits of an easy exchange of locations for the fibre stop and the long contact screw. Remove long contact screw and fibre stop and replace each one in the opposite hole.

Reverse contact breaker lever and replace so that the contact points match. Screw breaker lever axle in tight and lock threaded end to breaker cage.

Now replace bayonet lock latch and spring. Note that each end of the spring is secured. One end fastens in bayonet lock latch while the other or inside end fastens in breaker cage. Replace dog plate and secure with dog plate fastening screws. Lock screw heads to dog

plate. Fasten end cover with advance lever in place and the breaker assembly is ready for clockwise rotation.

Recharge rotating magnet; note that it is clean and free from clinging metal particles and replace in magneto housing. Turn magnet until marked tooth on distributor gear is up.

Take front end plate and put in position for matching gears. Turn large distributor gear until tooth marked *D* lines up with marked tooth on small distributor gear. Mesh gears and slide front end plate into place and fasten to magneto housing with nuts and screws provided. Replace contact breaker assembly. Turn rotating magnet until the number 1 on the distributor gear appears in the opening for the timing window in the front end plate.

Now hold the rotating magnet so that the contact points are just at the instant of opening and then replace the timing window so that the white mark therein will coincide with the mark on the large distributor gear directly above the number 1.

Re-mark the front end plate with new supplemental timing marks that will coincide with the original marks on the distributor gear. The new marks will be correct for clockwise rotation of magneto. Replace main cover and change rotation indicating arrow from anticlockwise to clockwise rotation. Change number discs to correspond with clockwise rotation as shown in distributor block diagrams and replace distributor blocks. The magneto is now ready for test as a clockwise (R.H.) rotating magneto.

If it is necessary that the direction of rotation of the magneto be changed it is strongly recommended that the magneto be sent to the factory for this purpose.

Adjusting End Play of Rotating Magnet.—As there is only 0.002 inch air gap between the rotating magnet and the pole shoes, and in consideration of the design of the ball bearings, it is imperative that there be a very careful adjustment of the axial or end play of rotating magnet between its bearings.

Since the rotating magnet exerts a certain amount of attraction between its poles and the pole shoes, when turned from the neutral position, advantage is taken of this pull to get the correct adjustment of the ball bearings.

The end play adjustment is really carried beyond the point where a mechanic could actually feel even the slightest hint of end play. The

correct adjustment is observed by turning the rotating magnet away from its neutral position and noting how far the trailing edge of the rotor slot can be from the edge of the opening between the pole shoes and still return to its neutral position. Obviously, the closer the edge of the slot must be to the pole-shoe edge in order to pull back to neutral, the tighter the bearings.

It has been found in practice that when the distance between the pole-shoe edge and the rotor-slot edge is from $\frac{3}{8}$ to $\frac{3}{4}$ inch, the adjustment is satisfactory, while $\frac{5}{8}$ inch is the desirable adjustment.

The adjustment of the end play is obtained by means of steel spacing washers which fit in between the inner ball races and the rotating magnet. Keep the total thickness of spacing washers just as nearly equal as possible on each end. These spacing washers come in thicknesses of 0.05, 0.1, 0.2, 0.3, 0.4, and 0.5 of a millimeter, which is approximately 0.002, 0.004, 0.008, 0.012, 0.016 and 0.020 inch, respectively.

Installing Outer Bearing Races.—The outer bearing races are insulated from the magneto by strips of a specially prepared material. They are also backed by washers of the same material which is very rigid and will stand considerable pressure. Thus the ball bearings are free from minute electric arcing which causes the balls to turn black and promote excessive wear. These ball races are readily removed by a specially designed puller and are easily pressed in by another tool.

There is a recess cut in the metal where the outer races fit. This recess allows the overlapping of the ends of the insulating strip. There is another recess cut in the metal back of the insulating washer. This is for oil.

In installing an outer race, first put the washer in so that the cut in it will line up with the oil recess. Then spread a few drops of oil evenly over one side of the insulating strip. Take strip up and bend it in a circular form, with the oiled side inside, and overlap the ends enough to allow the strip to fit easily into the container for the outer race. When it is released, it will expand against the container walls and the ends will overlap slightly in the recess cut for them.

Place outer race squarely inside the insulated strip and press until race seats against insulating washer. The race should have a light press fit which may be obtained by the selection of insulation strips of the proper thickness. Great care must be exercised in keeping in line the race and the front end plate, or the race and the magneto

housing as the case maybe, so that the race will not cut the insulating strip or, by not being seated squarely, it would result in serious injury to the ball races or the cage and ball assembly.

Contact Points.—The life of the contact points depends to a great extent on how clean they are kept. Therefore, take particular pains to keep them as clean as possible. File them only when it becomes absolutely necessary for the best operation of magneto.

The gap between contact points when fully opened should be maintained at 0.012 inch. Use the gage on the Scintilla wrench for this purpose. Keep points in alignment.

Adjusting Fiber Stop.—The fiber stop is mounted in the insulated support just back of the top of the breaker lever. Its function is to limit the travel of the breaker lever at high magneto speeds. The fiber-stop clearance is measured between the face of the stop and the back of the breaker lever. The clearance must be measured with the points fully opened.

The fiber-stop clearance must not be less than 0.002 inch. This may be obtained in a practical way by using a 0.002 feeler, placing it behind the breaker lever and turning rotating magnet until the points are at their maximum opening. The tension on the feeler, as it is pulled from between the back of the breaker lever and the fiber stop, should be just enough to allow it to be withdrawn easily.

Care should be taken in filing fiber stop so that when proper clearance is obtained and the breaker lever is pushed back against the stop the whole surface of the stop bears against the back of the breaker lever.

It is impractical to state a maximum fiber-stop clearance which could be applied impartially to all Scintilla magnetos, inasmuch as the fiber stops and camfollowers and contact points do not wear exactly alike.

Distributor Block Electrode Clearance.—There will be very little necessity for putting in new electrodes in the distributor blocks. Should it become necessary, however, it is very important that they have the correct clearance. The minimum clearance should be 0.030 inch. The maximum clearance should not be over 0.050 inch. Templates for measuring these clearances may be obtained from the manufacturer.

Adjusting Mesh of Large Distributor Gear.—This adjustment will rarely be found necessary. In the event that the large distributor gear requires replacement, adjust gear as follows:

To raise gear, loosen fastening screws on distributor gear axle flange and drift axle slightly to the right as viewed from the distributor gear side of the front end plate. To lower gear, drift axle slightly to the left. Tighten fastening screws for distributor gear axle and lock outer ends to outside surface of front end plate.

Timing Magneto by Means of Lights.—This practice can be followed very easily while magneto is on the repair bench and the coil is not installed, and will serve as a very accurate means of checking the internal timing of the magneto.

Once the coil is installed, however, and the magneto is mounted on the engine, the timing marks on the magneto will be found sufficiently accurate to meet all practical requirements for timing magneto to the engine.

With coil in place, the internal circuits and construction of the magneto are such that if an external source of current is applied to the contact points, there is the danger of the coil acting as an electromagnet and weakening the magnetic qualities of the rotating magnet, thus impairing the efficiency of the magneto.

Oiling the Magneto.—Proper oiling is of vital importance for the satisfactory operation of the magneto. Use the best grade of medium bodied oil obtainable.

Put from 30 to 40 drops of oil in the front oil holes or until it appears at the overflow hole for the distributor gear axle bearing. This hole is located about 1 inch below front oil hole cover. Put about 3 to 5 drops of oil in the back oil hole. Note that the felt wick in the bottom of breaker cage is thoroughly saturated with a heavy bodied oil.

Oil magneto thereafter at regular intervals of about 10 hours of running.

AIRPLANE ENGINE SUPERCHARGERS

Supercharging may be, briefly, defined as supplying air to the intake manifold of an engine at a pressure which is equal to or higher than the pressure of the surrounding atmosphere. In the ordinary type of internal-combustion engine the pressure in the intake manifold is lower than the pressure of the surrounding atmosphere due to the drop through the carbureter; therefore, if air is supplied to the intake manifold at a pressure equal to that of the surrounding atmosphere the principle

of supercharging is still applied as some initial pressure must be supplied to the entering air to overcome the drop through the carbureter.

In general, supercharging is used to obtain one or more of the following results:

1. To maintain the rated sea-level power of an engine at increased altitude.
2. To increase the power output for a given size of engine.
3. To decrease the engine size for a given power output.
4. To thoroughly mix and vaporize the air and the gasoline. This is accomplished by passing both the gasoline and air through the supercharger impeller and diffuser and can be used with either of the three principals given above.

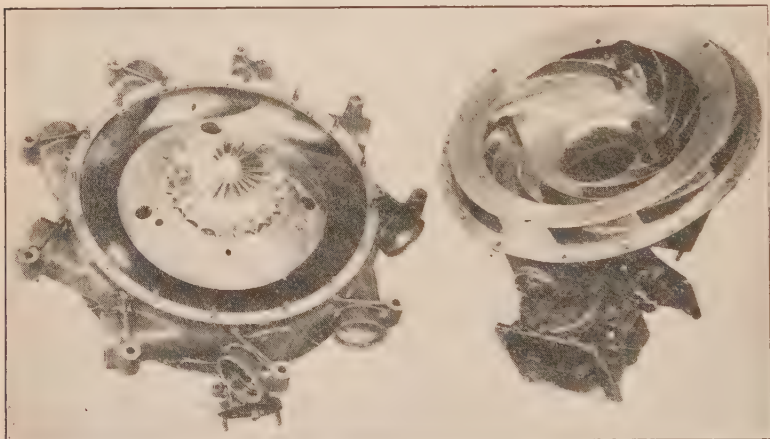


FIG. 10.—General Electric Co. type of supercharger.

The supercharger which the General Electric Co. manufactures consists of an impeller that is driven through gears by the gas engine and the casing which is made an integral part of the engine itself. Figure 10 shows the impeller and the halves of the casing of the General Electric supercharger which is used on the Wasp engine.

The impeller is made of duralumin and varies from 6 to 8 inches in diameter and weighing from 1½ to 2 pounds. The impeller operates at speeds of 10,000 r.p.m. and up, depending on the amount of supercharging required. The gear-driven supercharger is very easily applied

to radial engines and does not add any appreciable weight to the engine nor does it increase the length.

Some of the advantages which may be expected from the use of superchargers with airplane engines are as follows:

1. Increased maximum altitude. The ceiling of the average plane may be increased approximately 80 per cent by use of a supercharger.
2. Increased speed.
3. Increased rate of climb.
4. Better fuel economy at high altitude.
5. Better performance at low altitude.
6. The fuel is completely vaporized and uniform distribution to all cylinders is obtained.

Superchargers of the Root, or impeller type, are run much slower, as from 3,500 to 7,500 r.p.m. Both types require gearing of the best steel and workmanship obtainable and the bearings of the gear shafts must have careful attention. The fluctuation of engine speed in itself imposes severe stresses on the gear teeth.

Still another type of supercharger has been tried. This is driven from the exhaust gasses of the engine going through a small turbine which, in turn, drives a small centrifugal pump at high speed. This type is, however, still experimental.

Superchargers are also used on racing automobiles to increase the power obtained from an engine of given size and some advocate its use on commercial engines. There is more need for the supercharger on the airplane engine even if it does not often travel at very high altitudes but, as yet, it has not become part of the commercial engine.

ENGINE REDUCTION GEARS

Because the high speeds at which the modern airplane engine runs, in order to secure maximum power at minimum weight, there is a loss in propeller efficiency due to the limit placed on its diameter. For this reason it is desirable to use larger propellers on planes built for low speeds and so reduction gears are placed between the engine and the propeller. The gain in propeller efficiency is found to counterbalance the extra weight and the loss in the gearing.

Three types of reduction gearing are shown; the first the plain spur type gear, then the spur gear planetary gear reduction and finally two

types of bevel gear reductions. The spur gear reduction, (Fig. 11) was built by the Allison Engineering Company of Indianapolis for the Packard Company. Figure 12 is a planetary-spur gear reduction by the same concern, while Figs. 13 and 14 show two bevel gear reductions using different constructions. Figure 13 is the Jupiter gear, while

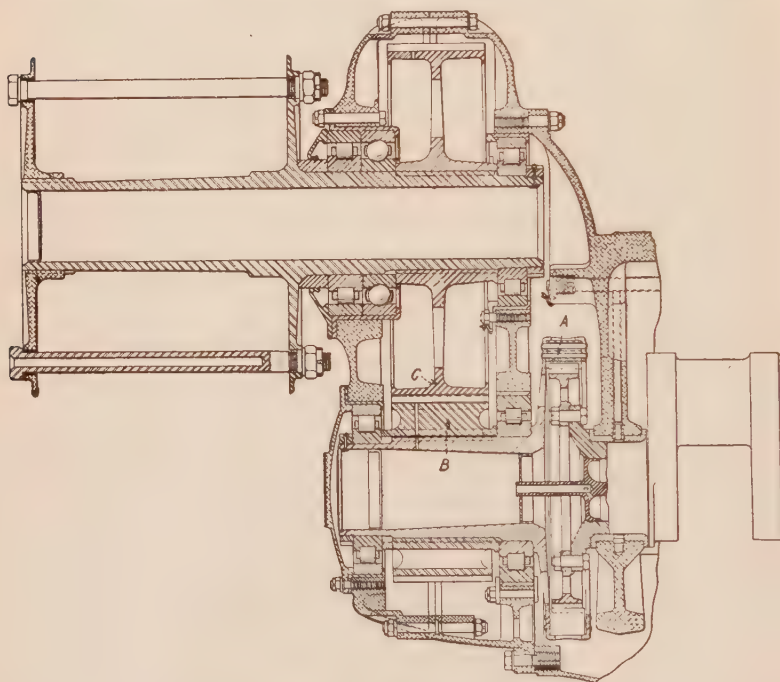


FIG. 11.—Spur gear reduction for Packard engine.

Fig. 14 is that used by the Pratt & Whitney Company for their Hornet engines when reduction is necessary.

In Fig. 11 the action is clear at a glance. In Fig. 12 the internal gear A, with its bell-shaped web, is bolted to the flange on the engine crankshaft and driven by it. At B is the large end of one of the planet gears, the small end of the same gear, C, driving final gear D, which, in turn, drives the propeller hub through the flexible coupling E. Ball and

roller bearings are used throughout. This reduction gear was used on Liberty engines.

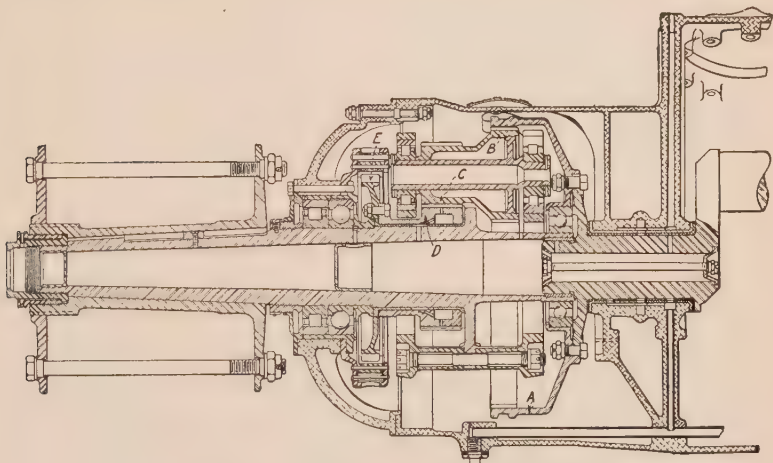


FIG. 12.—Spur-gear planetary reduction.

The Jupiter reduction gear (Fig. 13) incorporates the Farman patented, self-centralsing bevel reduction gear. The driving gear at the right is

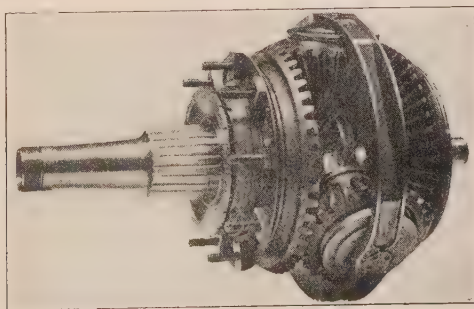


FIG. 13.—Jupiter bevel reduction gear.

connected to the crankshaft of the engine and drives the large gear at the left.

The construction of the Hornet reduction gear (Fig. 14) is entirely different, and is patented. The engine drives the bevel gear *A* which rolls the bevel gears as *B* between the driving gear and the stationary gear *C*. The ring that carries the bevel gears turns between the two bevel gears and drives the propeller sleeve at one-half engine speed through the toothed connection between the bevel-gear ring and the sleeve flange at *D*. Both the revolving shafts are run in large ball bearings with a roller bearing next to the crankcase. The small bevel gears also run in ball bearings.

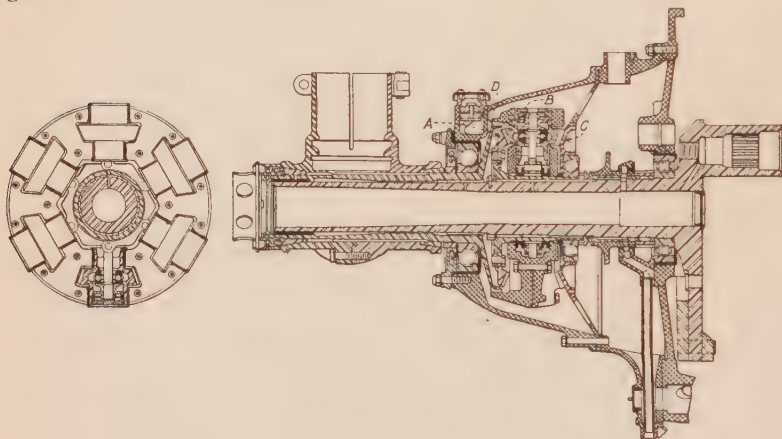


FIG. 14.—The Hornet bevel reduction gear drive.

Engine Starters.—Although many airplane engines are still started by pulling the propeller there is a growing tendency to use mechanical starters, following the automobile in this respect. Owing to the weight of a starting battery, small planes favor the inertia starter that is operated by hand. Larger planes, however, are using batteries for lighting and utilize the same battery for starting. The application differs from the automobile as the battery is not called upon to start the high-powered motor directly, as in automobile practice, but it simply turns a small motor that brings the inertia starter up to speed instead of doing this by hand.

The inertia starter simply stores energy in a small flywheel *A*, (Figs. 15 and 16) that is accelerated to high speed, from 10,000 to 16,000 r.p.m.,

either by hand crank or by a small motor. This stored energy is transmitted to the crankshaft of the engine by multiple-reduction

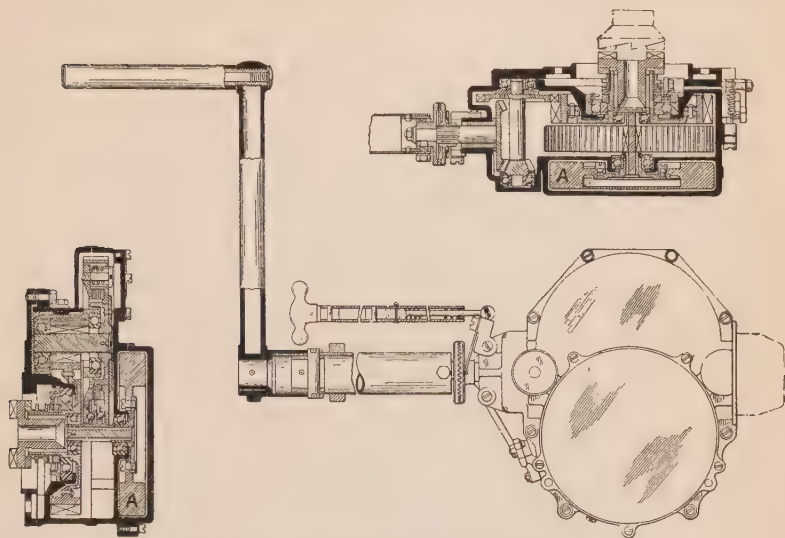


FIG. 15.—Aeromarine inertia starter.

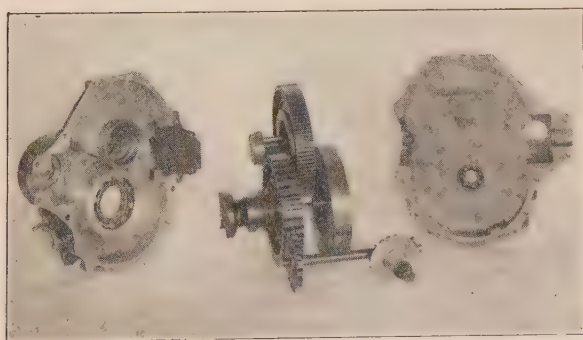


FIG. 16.—Gearing of Aeromarine starter.

gearing, through a driving clutch and an overload release. The crank is turned with a gradually increasing speed, much as hand-driven

cream separators, requiring from 15 to 30 seconds to bring the flywheel up to speed. The handcrank turns from 70 to 80 r.p.m. to secure the proper speed, and, if allowed to run down, will require from 10 to 15 minutes.

After the flywheel has been brought to speed the crank handle is removed, and the operating rod, *C*, pulled to engage the starting clutch with the crankshaft. Owing to the heavy gear reduction this clutch shaft is revolving rather slowly, but has great power and turns the engine over several times without difficulty. As soon as the engine fires, the starter clutch is thrown out of mesh automatically and, in case of backfire, there can be no injury to either the operator or the starter itself. As the starter does not engage with the engine until after the flywheel is up to speed, the temperature or the stiffness has no effect on the effort required to get the starter up to speed.

Among the well-known starters are the Aeromarine and the Eclipse, both operating on similar principles and both now built by the same company. The capacity of the Aeromarine starter is given as follows:

Cranking time, seconds	When cranked to these r.p.m. hand crank	Fly-wheel, r.p.m.	Starting energy available, pounds per foot	Approx. horsepower of engine this will start
15-20	42	8,000	1,715	200
25-30	63	12,000	4,287	400
35-40	83	16,000	6,860	800

The Eclipse starter is rated by the cubic inch of displacement of the cylinders rather than horsepower. One size, Series 6 being for engines up to 1,350 cubic-inch displacement and the Series 11 for engines up to 2,500 cubic inches. The weights are given as 23 pounds for the Aeromarine and from 19½ to 21½ for the Eclipse, both hand operated. In some cases, a booster or auxiliary magneto is mounted on the hand-operated starter to give a specially hot spark for starting.

For small engines of 100 horsepower or under, such as the well known OX-5, the makers of the Eclipse starter supply an electric starter that operates exactly as the starters in use on automobiles. A small pinion on the shaft of the starting motor engages a ring gear on the flywheel of the engine.

The Heywood Starter.—The Heywood starter, (Fig. 17) works directly in the cylinders themselves. It consists of a small air compressor geared to the engine that accumulates air pressure in a steel-tube tank, 6×26 inches, and containing about $\frac{1}{2}$ cubic foot of air which is compressed to 400 pounds per square inch; this pressure being controlled by a safety valve, being but one-third of the pressure that the tank receives in test. A small copper tube leads to each cylinder; the passage of air



FIG. 17.—Heywood compressed air starter.

being controlled by a distributor that is timed with the engine. A pull of the starter button admits high-pressure air to the cylinder or cylinders that are on their power stroke, forcing the pistons down and turning the engine at about 300 r.p.m. At the same time a small amount of compressed air carries a mixture of gasoline into the cylinders that is fired and starts the engine, regardless of weather conditions. Should the starter button be pulled while the engine is in motion the starter acts as an accelerator and does no damage. The maximum weight,

including all parts, is given as 30 pounds. Figure 17 shows a Heywood starter in place on a Whirlwind engine.

Electric Generators for Airplane Use.—The airplane is following somewhat in the footsteps of the automobile regarding the use of storage batteries to operate running lights, landing lights, special lighting equipment, and starters. This demand led to the development of the voltage regulated generator, to be driven either from the engine or by a small propeller, the voltage regulation keeping the battery at nearly full charge. The regulators are set for a voltage of $14\frac{1}{2}$ volts for charging a 12-volt battery, as is generally used. The charging voltage can, however, be regulated for special conditions. Where the generator is wind driven the use of a single-bladed propeller is quite common, it being easier to balance one blade by means of a counterweight on the other end of the hub than by using a second blade. Both wind-driven and engine-driven generators are similar except that, as the wind-driven generators usually run at a much higher speed, the windings are varied to suit.

Engine-driven generators weigh from 15 to 20 pounds depending on the output demanded. The normal speed is 2,250 and the output from 15 to 25 amperes. These figures refer to the Eclipse generator.

Airplane Landing Gears.—Landing gears must be both strong and resilient to support the plane in landing and prevent too much of a shock even when the landing is not as smooth as might be desired. A little error in judging speed or distance from the ground makes a great difference in the stresses imposed on the landing gear and on the whole plane. Then, too, even slight inequalities in the surface of the field that would not be noticed at slow speed become very evident at a high-landing speed.

The two main types of landing gears are those having a solid or continuous axle from wheel to wheel and what is known as the "split" type of gear, in which each wheel is carried on an independent landing bracket built out from the lower part of the fuselage. The tendency, at present, seems to be toward the split type of landing gear as can be seen from the illustrations in Sec. II.

Among the earlier efforts to increase the speed of planes was the trials of the retractable landing gear in which the wheels were drawn up into pockets in the fuselage after the plane was in the air. The object, of course, was to reduce the parasite resistance of the wheels

and the landing braces as much as possible. This method did not grow into favor for land machines but has been adopted by builders of flying boats, notably Loening, Fokker, and Sikorsky, in their amphibian planes, to enable them to land on either land or water. In the Loening design the wheels disappear into the hull of the boat while in the Fokker they fold into a horizontal position at the end of the stream-lined supports that also raise into a horizontal position.

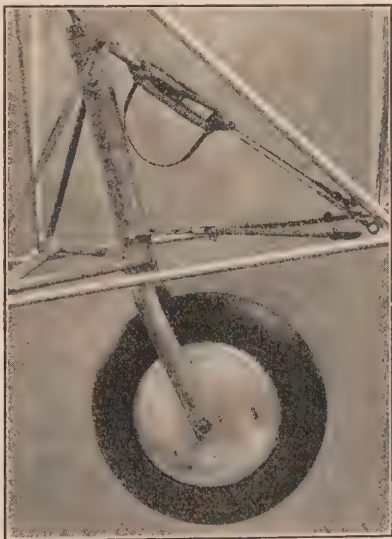


FIG. 18.—Fairchild tail wheel mounting.

Shock absorbers and brakes are now standard equipment on many planes, some of which are illustrated here.

Some plane builders are using small wheels under the tail of the fuselage instead of the skid. The use of brakes has made the skid unnecessary in retarding the plane after it lands. The tail wheel on the Fairchild, Fig. 18, is hung in a double triangular frame, its movement being checked by the heavy rubber bands shown.

Shock Absorbers.—Shock absorbers of various kinds are taking the place of the rubber-band devices that were first used to lessen the shock of landing the plane. Among the mechanical devices is the Aero

Landing Strut (Fig. 19) and which is built into or placed between the axle of the landing gear and the fuselage of the plane. The strut consists of telescoping cylinders filled with oil and air. Within one of the cylinders is a piston and valve mechanism that absorbs landing shock through the use of compressed air and oil.

When the wheel strikes the ground the blow is transmitted to the strut piston which absorbs the impact by sliding up into the cylinder and building up an air pressure as it moves, and cushions the shock.



FIG. 19.—Aerol landing strut.

When the piston reaches the top of its stroke, the oil-controlled check valve operates automatically and prevents recoil. The air pressure built up in the cylinder is dissipated through the hydraulic action and returns the piston to its normal position ready for the next impact. This action eliminates all rebound except that due to the tire.

When the plane is taxiing normally across the field the strut is compressed to about 75 per cent of the full extension when in flight. This indicates that the static load of the plane only causes the piston to move 25 per cent of its full stroke. This 25 per cent compression forms the air cushion for the initial landing impact and permits the gradual

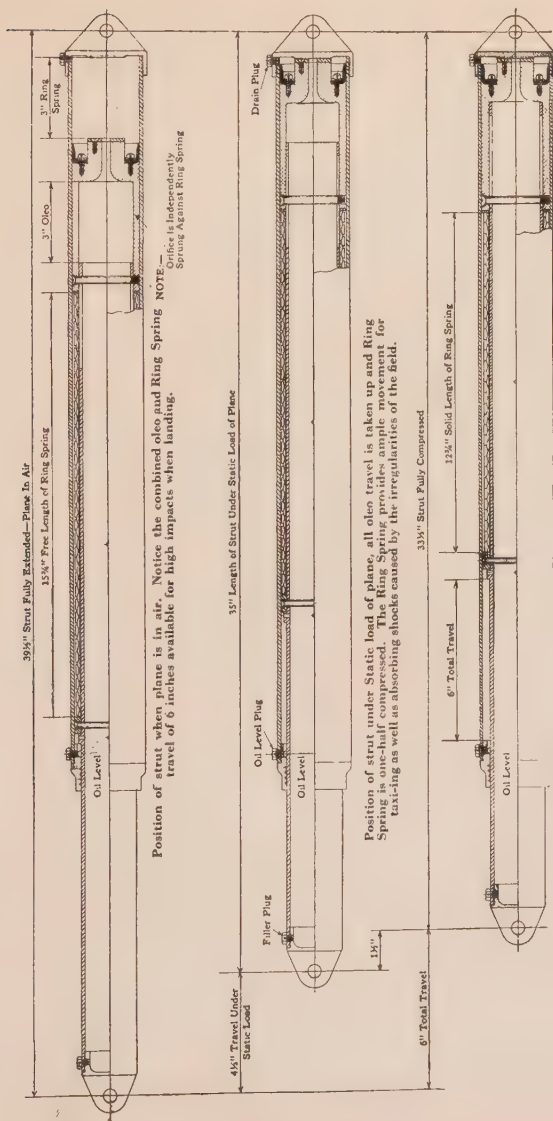


Fig. 20.—Edgewater strut with unusual spring construction.

building up of load over an appreciable time so that what would otherwise be jerky hops become gentle undulations.

The Waco shock absorber is shown in detail in Sec. III in connection with the rigging of the Waco plane.

The Edgewater Strut.—One of the problems in a landing-gear strut is to get proper spring action for taxiing and sufficient cushioning for landing; at the same time keeping down the weight. In the Edgewater strut, Fig. 20, an unusual spring is combined with the oleo piston. The spring is made up of two parts; a series of inner and outer rings with angular surfaces where they bear on each other. In action, the inner-spring rings are compressed in diameter, while the outer rings are enlarged. This type of spring is said to absorb two-thirds of the work put into it but to give back only one-third in recoil. There are no packing glands and oil leakage is negligible as the oil never gets above the test plug which is lower than the top of the outer tube. Once in position this strut needs no packing adjustments or the addition of air, or other attention.

Stearman Rubber-draulic Landing Strut.—This type of landing strut combines the use of rubber shock cord and hydraulics so as to handle the racking stresses of both landing and taxiing. The method of combining these two shock-absorbing elements is shown in

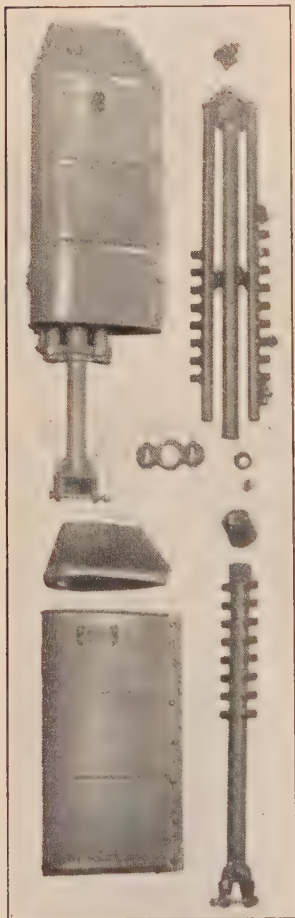


Fig. 21.—Stearman combined hydraulic and rubber landing strut.

Fig. 21, where it will be seen how the hydraulic cylinder is in the center of the three tubes forming the upper member and that the plunger goes into the cylinder beneath that slides between the two outer arms with the

projections that carry the rubber shock-absorbing cords. The whole mechanism is enclosed in the stream-lined casing that both protects it and reduces the air resistance. This is shown in place in Fig. 22.



FIG. 22.—Stearman landing strut.

Airplane Wheels and Brakes.—It is very necessary that wheels used in airplane landing gears be sufficiently strong to withstand the shock incident to landing the plane, even under adverse conditions, such as rough ground and uncertain light. One of the wheels used for this purpose is known as the Sauzedde and is illustrated in Fig. 23. This is a closely laced-wire spoke wheel and is made in sizes from 28×4 to 54×12 , the latter being capable of sustaining a weight of 50,000 pounds. These wheels are made to suit a large variety of plane requirements.

The Bendix wheel is made of aluminum-alloy sheets fastened to a long hub and having one side recessed to carry a braking mechanism

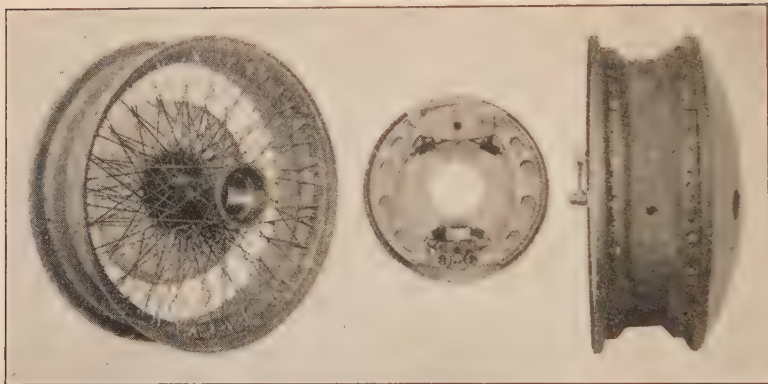


FIG. 23.—Sauzedde wire landing wheel and brake,

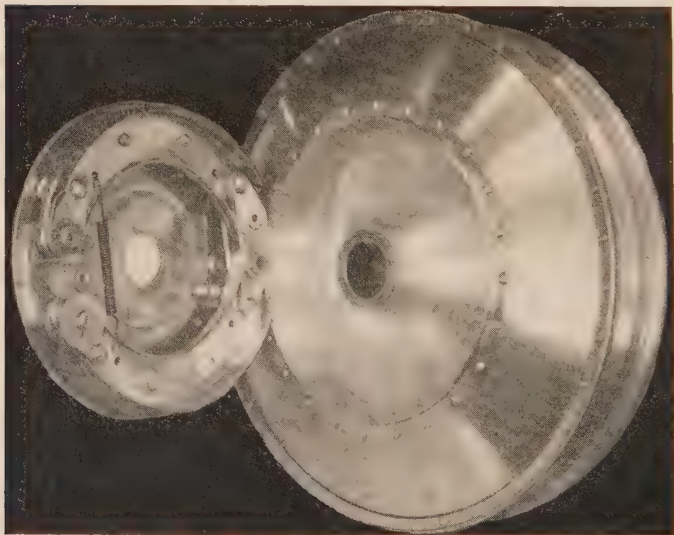


FIG. 24.—Bendix sheet alloy wheel and brake.

as seen in Fig. 24. The mechanism is on the side of the wheel next the center of the axle as in automobile construction. Brakes are becoming a part of airplane landing gear, removing the need of the tail skid that tears up the surface of a landing field. The brake gives the pilot much better control of his plane in landing and also enables him to hold his plane by the brake until ready to take-off. The use of the brake makes possible the use of a tail wheel instead of the skid.

This brake is built on the "servo" principle so that a pedal movement of from $2\frac{1}{2}$ to $4\frac{1}{2}$ inches affords ample braking for planes weighing from 3,000 to 10,000 pounds. The accompanying table shows the dimensions and capacities of these wheels and brakes:

SPECIFICATIONS OF BENDIX WHEELS

Size		Approximate weight, pounds		Minimum required braking load, S.A.E. standard		Axle		Maximum tire load	Oversize tire
Wheel	Brake, inches	Plain wheel	Wheel and brake	Radial, pounds	Side, pounds	Diameter, inches	Length, inches	Half maximum plane weight, pounds	
14 × 3	None	None	...	5,000	1,800	0.745	4	400	None
18 × 3	10	None	...	6,000	2,000	1.245	5	525	20 × 4
24 × 3	10	None	15	7,500	2,500	1.495	6	650	26 × 4
28 × 4	10	None	17	10,000	2,750	1.688	6	1,000	30 × 5
30 × 5	12	13	23	11,000	3,300	2.188	7.25	1,600	32 × 6
32 × 6	12	18	29	13,500	4,050	2.188	7.25	2,200	36 × 8
36 × 8	12	20	31	20,000	6,000	2.688	7.25	4,000	None
36 × 8	16	...*	...	20,000	6,000	2.688	8.5	4,000	40 × 10
44 × 10	20	40	65	35,000	10,500	3.188	10.0	6,000	None
54 × 12	20	None	100	50,000	15,000	3.937	12.0	9,000	None

* The 14 × 3 and 18 × 3 plain wheels are primarily tail wheels and are being designed as such. 24 × 3 and 28 × 4 plain wheels could be built but are not recommended.

Graphite bronze bearings are used and they must *not* be lubricated. The axle diameters shown in the table *must* be adhered to within 0.001 inch or operation of brakes will not be satisfactory.

Another type of airplane wheel is the Kelsey-Hayes, a wire-spoked wheel of usual construction and made in the sizes shown in the accompanying table:

MAIN DIMENSIONS OF AIRPLANE WHEELS KELSEY-HAYES WHEEL
CORPORATION

Weight, pounds	Size of wheel	Width of rim "D," inches	Size of tire	Hub flange			
				Length "B," inches	Bore "A," inches	Outside diameter "C," inches	Number and diameter spokes
3.04	14 × 3	2½	14 × 3	4	0.627	....	16—0.104
5.10	18 × 3	2½	20 × 4	5	1.00	1¾	36—0.104
5.10	18 × 3	2½	20 × 4	5	0.750	1¾	36—0.104
5.60	18 × 3	2½	20 × 4	5	1.250	2¼	36—0.104
	26 × 4 CL	...	26 × 4	6	1.50	....	40—0.104
	26 × 4 CL	...	26 × 4	6	1.50	3	52—0.135
7.43	26 × 4 SS	2½	26 × 4	5	1.50	2½½	40—0.104
	27 × 3½	2½	28 × 4	6	1.690	2½	52—0.104
	27 × 3½	2½	28 × 4	6	1.50	3	52—0.135
13.02	27 × 3½	2½	28 × 4	7¼	2.197	3¾	64—0.104
19.00	27 × 3½	2½	28 × 4	6	1.750	2½	60—0.135
	27 × 3½	2½	28 × 4	6	1.50	3	52—0.135
20.11	27 × 3½	2½	28 × 4	6	1.750	3½	60—0.135
13.50	28 × 4	3	28 × 4, 30 × 5	7¼	2.197	3¾	64—0.104
	28 × 4	3	28 × 4, 30 × 5	6	1.697	2¾	52—0.104
	28 × 4	3	28 × 4, 30 × 5	7¼	1.750	3¾	64—0.104
	28 × 4	3	28 × 4, 30 × 5	7	1.750	3½½	64—0.135
	28 × 4	3	28 × 4, 30 × 5	7¼	2.197	3¾	64—0.104
	28 × 4	3	28 × 4, 30 × 5	6	1.50	3½½	64—0.104
16.90	30 × 5	3½	30 × 5, 32 × 6	7¼	2	3¾	64—0.104
	30 × 5	3½	30 × 5, 32 × 6	6.580	2	3½½	72—0.135
24.00	30 × 5	3½	30 × 5, 32 × 6	6.580	2	3¾	72—0.135
19.90	32 × 6	4.20	32 × 6, 36 × 8	7¼	2.197	3¾	64—0.135
18.75	32 × 6	4.20	32 × 6, 36 × 8	7¼	2.197	3¾	64—0.104
29.83	36 × 8	5½	36 × 8	7¼	2.502	4¾	96—0.135
28.50	36 × 8	5½	36 × 8	7¼	2.178	4	80—0.135
					2.197	4	80—0.135
					2.697	4	80—0.135

Airplane Tires.—Tires for use on airplanes have been standardized and the sizes shown in the table below are made regularly for aviation use. The information is clear in most cases, A.W.T. meaning "all weather tread" F. B. "flat base," and D. C. standing for "drop center rim." Of special interest is the information on the load the tires can carry and the proper inflation which runs from 50 to 70 pounds pressure.

Size	Type	Rated		Dimensions				Weight			Rim size	
		Plies	Load	Infl.	O.D., inches	S.D., inches	Wheel diam- eter, inches	Case	Tube	Flap		
Clincher tires:												
26 X 4.....	Smooth	4	750	50	25.81	3.95	18	8.41	1.75	0.39	26 X 4 CI	
750 X 125.....	MM smooth	4	1,000	50	28.88	4.98	20.156	10.53	2.07	.....	2 - 2	
800 X 150.....	MM smooth	4	1,650	55	30.67	6.12	20.156	13.07	2.8	.....	2 - 3	
900 X 200.....	MM smooth	6	3,100	65	34.91	7.78	20.375	23.50	4.95	.....		
Straight side:												
14 X 3.....	AWT	4	600	50	14.15	3.15	8	2.01	0.67	.....	14 X 3 - 8 inches	
20 X 4.....	AWT	4	800	50	19.97	4.00	12	6.40	1.15	0.15	18 X 3 - 12 inches	
26 X 4.....	AWT	4	1,000	50	25.91	3.94	18	8.62	1.75	0.18	24 X 3 - 18 inches	
28 X 4.....	Smooth	4	1,000	50	27.82	4.17	20	9.04	1.84	0.2	28 X 4 - 20 inches	
30 X 5.....	Smooth or AWT	4	1,600	50	29.43	5.12	20	11.35	2.93	0.25	30 X 5 - 20 inches	
32 X 6.....	Smooth or AWT	4	2,200	55	31.32	6.23	20	13.84	3.18	0.25	32 X 6 - 20 inches	
36 X 8.....	Smooth	6	4,000	60	34.90	8.58	20	27.16	5.13	0.3	36 X 8 - 20 inches	
40 X 10.....	AWT	8	6,000	65	38.20	9.87	20	45.10	9.27	0.375	40 X 10 - 20 inches	
44 X 10.....	Smooth (F.B.)	8	6,000	65	43.23	10.42	24	53.80	9.8	4.57	See below	
44 X 10.....	Smooth (D.C.)	8	6,000	65	42.20	9.87	24	50.80	9.8	4.57	44 X 10 - 24 inches	
54 X 12.....	Smooth	10	9,000	70	52.12	12.49	30	82.26	16.22	0.54	54 X 12 - 30 inches	

800 X 150 MM is oversize for 750 X 125.

30 X 5 can be used as oversize for 28 X 4.

32 X 6 can be used as oversize for 30 X 5.

36 X 8 can be used as oversize for 32 X 6.

40 X 10 can be used as oversize for 36 X 8.

No oversize is available for other sizes.

All straight side sizes listed above, except 44 X 10 F.B. (Flat Base) are used on drop center rims.

The 44 X 10 F.B. is designed for use on a 40 X 8 flat base rim only. It is not properly interchangeable with drop center type; therefore, when placing orders for this size please be specific as to type desired (flat base or drop center).

¹ Airplane Tire and Accessories Department, The Goodyear Tire and Rubber Company, Akron, Ohio.

Floats or Pontoons.—Floats or pontoons, as they were formerly called, for permitting planes to land on the water, are made from both wood and metal, with the trend toward metal. Plywood and composite materials are also used, but strength and the tendency of wood to absorb water and so add materially to the weight of the float, has brought metal into favor. Both strong aluminum alloys and Monel metal are being used at present.

A float for a Navy plane is shown in different stages of construction in Figs. 25 to 27. A fixture holds the different members in position while they are being riveted; Fig. 26 showing the cross-members and

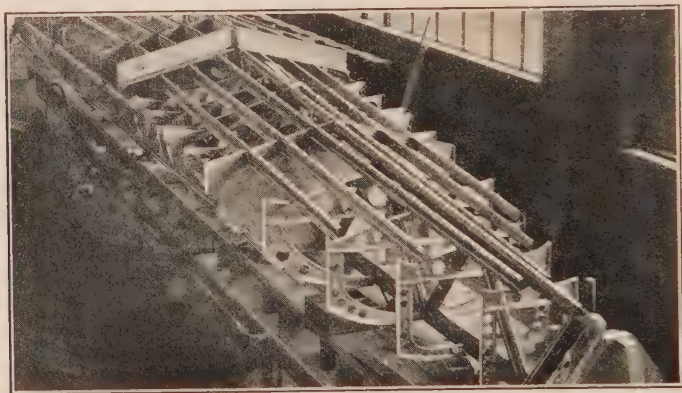


FIG. 25.—Construction of metal float for Navy plane.

the bulkheads that divide the pontoon into compartments. Next comes the covering of the bottom with sheet metal and, finally, the completed float is seen in Fig. 27. This shows the cast pockets that receive the struts from the fuselage, the ten hand hole plates and the walk, or runway, in the center. The floats are 24 feet 6 inches long, 44 inches wide, and $28\frac{3}{8}$ inches deep. These were built by the Glenn L. Martin Co.

Another type of float built by the Edo Aircraft Corporation for smaller planes, is shown in Figs. 28 and 29. The first shows the method of construction and the other a pair of the completed floats on a Fokker plane. It will be noted that this design gives a wide, flat top that is easy to walk on and that the joint of the side and top sheets is vertical

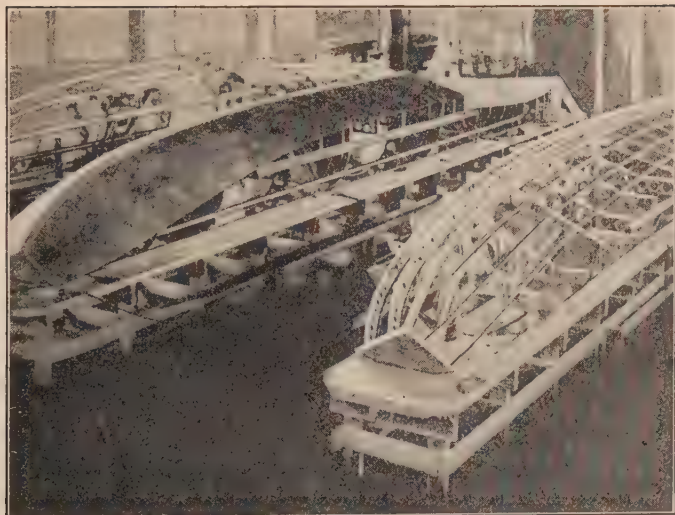


FIG. 26.—Floats in different stages of construction.

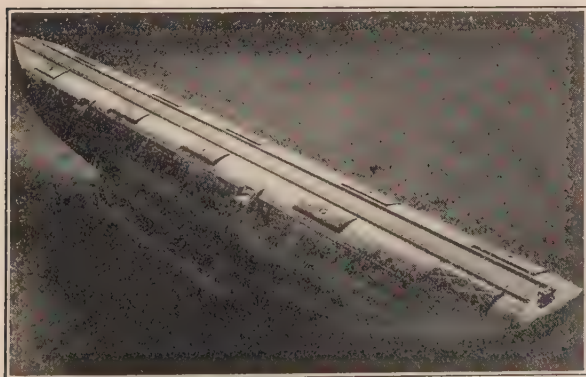


FIG. 27.—Completed float ready for mounting.

making a raised edge each side of the runway that aids materially in preventing the foot slipping off the float.

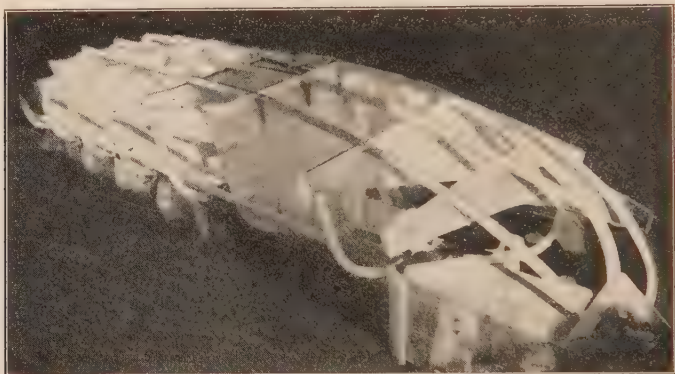


FIG. 28.—The Edo method of float construction.

Floats of Monel metal & are also used, the Navy having a number of seaplanes so equipped. Being a natural alloy of copper and nickel the



FIG. 29.—Edo floats on Fokker plane.

metal is not subject to corrosion, but is, of course, heavier than aluminum alloys.

PARACHUTES

Parachutes are standard equipment in Army, Navy, and Mail service. The oldest and best-known commercial parachute in this country is the Irvin Air Chute, the 24-foot size being standard for general use and is known as the "service parachute." It weighs about 18 pounds



FIG. 30.—Seat- and lap-packed Irvin parachute.

and the average rate of descent is 16 feet per second. They are also made in 22- and 28-foot sizes, these being for use in exhibition and training jumps. They are made in two styles for general use, the lap pack and the seat pack, the name denoting the way they are worn as seen in Fig. 30. For use in lighter-than-air craft a back pack is provided

which permits the wearer to walk about the ship or into the rigging. The 28-foot size is usually made in the back pack. It is, of course, slower in descent than the smaller chutes.

Parachutes, to be effective, must enable the aviator or passenger to leave the aircraft regardless of its, or his position, and the operation must not depend on his falling from the craft. The chute must open promptly on being released and strong enough to stand the shock of a 200-pound person falling at a speed of 400 miles per hour. It must be steerable to a reasonable degree by pulling down on one side or the other. The harness must hold the occupant, regardless of his position, and be as comfortable as possible.

The fabric used is a woven high-grade silk and the suspension cords are also of silk. These will each take a pull of 400 pounds. The cords are continuous from one side of the harness to the other, going over the top of the chute, and are free from knots and splices.

A small pilot chute, 30 inches in diameter, with steel ribs and a spring that opens on release from the pack, is fastened to the center of the main chute. When the container opens, the pilot chute springs out, catches the air, and holds the main chute out of the line of flight as well as insuring its opening. The pull ring by which the wearer releases the pack, the pilot chute first, is large and easily reached. The pull ring is under the left arm in the seat pack and on the top of the lap pack next to the body.

The Russel Lobe Parachute.—The Russel Lobe parachute has been designed to give rapid opening under almost any condition and without excessive shock. Its appearance is shown in Fig. 31. It is said to be easily packed even without experience by following instructions accompanying the chute and is entirely operated by the user, without mechanical appliances of any kind. It is made in both silk and cotton and in two sizes for regular use. Special, large parachutes of 50-, 60- and 70-foot diameter, for controlling the entire plane, are also made to order.

The construction of the parachute and pack eliminates the necessity for repeated repacking in order to insure efficiency. Repacking is advised only for inspection of the condition of the materials used in construction of the parachute canopy. These parachutes in constant use for more than 90 days, have proven efficient for emergency use. Inspection and repacking every 60 days is all that is necessary to insure the proper functioning of the "Lobe" parachute complete.

To Operate the "Lobe" Parachute For Safe Descent.—Be sure the leg strap snaps and breast strap snap are fastened and the rip cord ring of the parachute is in the pocket on the harness before leaving the ground.

If it becomes necessary to jump, be sure to be clear of the falling plane before pulling rip cord. *Never remove rip cord ring from pocket until clear of plane and ready to operate parachute.* When pulling on rip cord ring, do so with vigorous jerk. Although a 10-pound pull is all that is required to operate the parachute, and while it will function



FIG. 31.—Russel Lobe chute in action.

perfectly with a steady pull, it is recommended that a vigorous jerk be applied. This insures maximum speed of operation under all conditions and positions in which the wearer might be placed in respect to his line of flight.

To change the direction of, or lessen the drift, due to wind, during descent, reach up and pull down on one or more lift webs on the side of the parachute facing the desired direction. This method may be used to select a safe landing place.

Upon landing, let your knees bend under you as you would if jumping from a 6-foot elevation. Use cords to canopy to collapse parachute after landing, if heavy wind is blowing.

SECTION VIII

AIRCRAFT INSTRUMENTS

Aircraft instruments are playing a constantly increasing part in the progress of aviation. The great expansion of the use of aircraft for commercial purposes under all kinds of weather conditions has made the importance of accurate instruments more fully realized. Instruments are now manufactured to indicate or record practically every possible phase of aircraft performance. They have been improved and perfected to such a point that they are now accepted as being reliable under all flying conditions.

Aircraft instruments are being used to a far greater extent than ever before. Even the lowest price sport airplanes are being sold with surprisingly complete instrument equipment. Commercial plane manufacturers frequently pay as much as \$3,000 for just the instrument equipment of their large planes which indicates the importance which they attach to them.

The famous flights of Colonel Lindbergh and other pilots of reputation have impressed all air-minded people with the importance of proper instrument equipment. With hardly an exception it can be stated that pilots famous for their achievements are those who use the most instruments.

The development of aircraft has been dependent to a large extent on the perfection of aircraft instruments. The efficiency of present-day aircraft has come about largely from the performance data obtained from instruments developed for the purpose. Until recent years, instruments have been used largely to indicate engine performance and plane stability. With the development of airplanes capable of long sustained flights, instruments comparable with those used in ocean navigation have been developed for purposes of aerial navigation.

Aircraft instruments may be considered to fall within three classifications, namely; power plant or engine instruments, flight or stability

instruments, and navigation instruments. The most commonly used instruments might be listed under these classifications as follows:

Engine Instruments:

- Tachometer, engine-revolution indicator,
- Thermometers, oil and water,
- Pressure gages, fuel and oil,
- Fuel-level gages (gasoline gages),
- Fuel-flow meter,
- Ignition switch.

Flight Instruments:

- Altimeter,
- Air-speed indicator,
- Compass (Magnetic),
- Turn indicator,
- Lateral and longitudinal inclinometer,
- Rate-of-climb indicator,
- Air-distance recorder,
- Clock.

Navigation Instruments (in addition to those listed above):

- Earth-inductor compass,
- Speed and drift indicator,
- Sextant or octant,
- Sun compass (for Arctic and Antarctic use).

The most recent development in aircraft instruments is the production of smaller instruments than have been made heretofore. All manufacturers are now making practically every instrument in the new standardized case which has a $2\frac{3}{4}$ inch dial. The maximum case diameter is $3\frac{1}{4}$ inches and the four mounting holes are equally spaced on a $3\frac{1}{2}$ -inch diameter. The smaller instruments are neater in appearance than the older types and can be spaced closer together on the instrument board (see Fig. 1).

Vertical instruments, *i.e.*, instruments having vertical reading scales instead of round dials, are not as popular as they were a few years ago. The difficulty of installation and the added cost, due to the difficulty of manufacture, have caused commercial plane manufacturers to abandon them. They are now being used only on fighting planes where lack of instrument board space makes their use imperative.

Instrument boards for airplanes are now almost universally made of metal, usually duralumin. It has also become the general practice to mount all instruments from behind the board so that only the dial and rim are visible. An example of this type of mounting is shown in Fig. 1. This greatly improves the appearance of the instrument board. Some

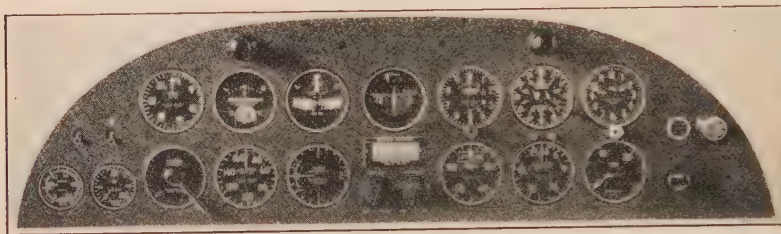


FIG. 1.—Instrument board well equipped with modern instruments.

instrument manufacturers are now mounting their instruments on invisible studs riveted on the back of the boards which enhance still further the appearance of the board due to the absence of screw heads.

DESCRIPTION OF INSTRUMENTS

Tachometer.—The function of the tachometer is to indicate the speed of the airplane engine in r.p.m. The speed is indicated by means of a flexible shaft which connects the camshaft or some other rotating part of the engine with the instrument. There are two common types of tachometers in use at the present time; namely, centrifugal and chronometric. The electric tachometer is beginning to make its appearance but as yet is not used to any extent.

The chronometric tachometer consists of a mechanism timed to indicate the revolutions of the engine at either $\frac{1}{2}$ - or 1-second intervals. This is more accurate than the centrifugal type, but because of its more intricate mechanism, is somewhat less dependable. The centrifugal type, as shown in Fig. 2, consists of a small flyball governor which operates the indicating hand.

When installing a tachometer be sure that the drive cable does not become cramped in its outer casing because of too short a radius in bending it between the engine and the instrument. The shaft must be exactly the right length for the outer casing, for when it is either too

long or too short it causes trouble. The inner shaft should protrude $1\frac{1}{8}$ inch from the outer casing, according to the standards of the Society of Automotive Engineers (S. A. E.) as shown in Sec. XIV, page 599. When these requirements are complied with no difficulty should be experienced. It is necessary to grease the inner shafting occasionally to reduce friction between it and the outer casing.

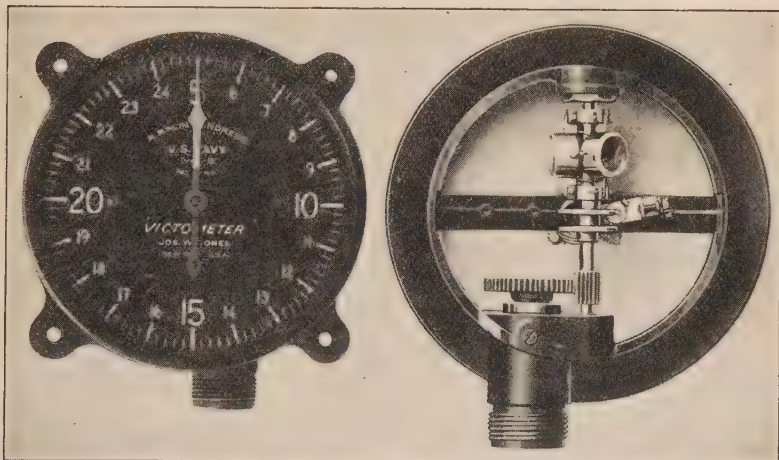


FIG. 2.—Tachometer showing mechanism.

Thermometers.—Water-cooled engines usually have two thermometers; one to indicate water-outlet temperature and the other to show the temperature of the lubricating oil. Sometimes both water-intake and water-outlet thermometers are used. Air-cooled engines require only the oil thermometer.

These thermometers consist, in principle, of a pressure gage connected to the engine with a small metal tube on the end of which is a bulb filled with either gas or liquid under pressure. This bulb is inserted in the oil or water, the temperature of which is to be indicated. The change of temperature causes the gas or liquid to expand or contract creating pressure in the indicating mechanism which indicates the temperature.

The installation of these instruments is not difficult. Care should be taken not to damage the tubing, for if the gas or liquid is allowed to leak out, the thermometer will not function properly. If the tubing is

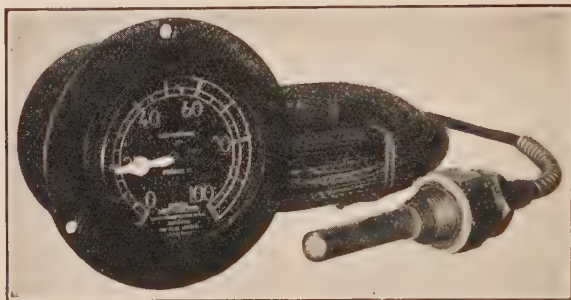


FIG. 3.—Oil or water thermometer.

longer than necessary for the installation, it should be coiled up and fastened to some convenient part of the plane. Figure 3 illustrates an engine thermometer.



FIG. 4.—Oil pressure gage.
(Consolidated Instrument Co.)

Pressure Gages.—These instruments are well known and need little or no explanation. A pressure gage, (Fig. 4) consists of a Bourdon tube which expands under pressure, causing the hand to rotate and indicate the pressure exerted. These gages are used to indicate the pressure exerted. These gages are used to indicate both engine oil and fuel pressures. They are now sometimes used to indicate pressures on hydraulic shock absorbers. They are connected to the engine with soft copper tubing. Care should be taken to see

that this tubing does not vibrate when the engine is running as excessive vibration causes the tubing to crystallize and break. Many forced landings have been caused by such trouble.

Fuel-level Gages.—There are a number of types of fuel-level gages on the market. They may be divided into two general classes,

however; direct reading and distance reading. Direct-reading gages are usually of the float type commonly found on automobiles. Distance-reading instruments are usually of the *hydrostatic* type which indicate the amount of gasoline in the tank by actually measuring its weight.

The operation of a hydrostatic fuel-level gage depends upon the simple principle that the pressure exerted by a volume of liquid is proportional to its depth. A "hydrostatic cell," forming part of the gage system, is placed at the bottom of the tank. This cell is filled with air, and the weight of the liquid above it compresses this air. A small tube runs from the cell to a fitting on the outside of the tank, and from this fitting a connection tube goes to the gage. These tubes transmit the air pressure to the gage, which is a sensitive pressure indicator and is calibrated so that this air pressure is translated into gallons of fuel or other units of weight or volume.

This would complete the system were it not for the fact that because of the expansion of the air in the cell and tubing, due to changes of temperature and altitude, a small amount of air is occasionally lost. To assure the accuracy of the indication, the balance of the system must be maintained by replacing lost air. For this purpose a small pump is used in connection with the gage, either integral with it or as a separate unit. Once a day, or whenever it is necessary to know the fuel level with absolute accuracy, the knob of the pump is pulled out once and released. On the return stroke the pump automatically replaces the correct amount of air to balance the system and restore the accuracy of indication. It is not necessary to operate the pump each time the gage is read, as the indication is continuously correct, except for very slight errors due to temperature and altitude.

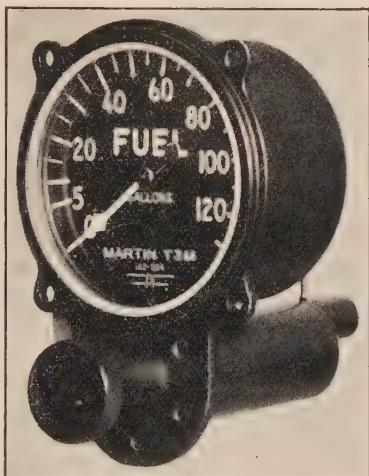


FIG. 5.—Hydrostatic fuel gage.

A hydrostatic fuel-pressure gage and pump unit are illustrated in Fig. 5.

Fuel-flow Sight Gage.—The fuel-flow sight gage, shown in Fig. 6, is a device inserted in the gasoline feed line which allows the pilot to see that gasoline is flowing through the tubing, thus assuring him that the line is clear. The gage is so constructed that the gasoline is plainly visible when passing the glass window. This is only a rough check on the fuel flow. For accurate indication of fuel consumption a fuel-flow meter is used.

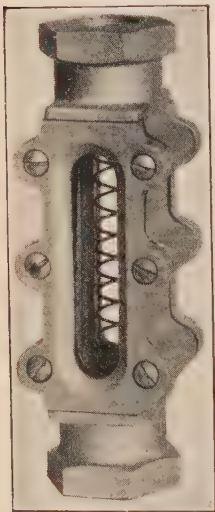


FIG. 6.—Fuel sight-gage.



FIG. 7.—Continuous fuel-flow meter.

Fuel-flow Meter.—The fuel-flow meter gives a continuous indication of the rate at which the airplane engine is consuming fuel. It reads directly in gallons per hour. The pilot can see at a glance the effect of changes in setting of throttle, mixture, heater, or spark controls. These instruments operate on the venturi principle and consist of a calibrated venturi tube placed in the fuel-feed line and connected to the indicating instrument on the board. Figure 7 shows this type of instrument.

Altimeter.—The altimeter, used to determine the height of aircraft, is simply a refined aneroid barometer, the dial of which is graduated in units of height above sea level instead of units of pressure. It is further distinguished from a barometer by the fact that its dial may be rotated so that any elevation or any barometric pressure may be taken as zero.

As a result of many experiments, the average relation between altitude and barometric pressure has been established. It must be remembered that these are *average* figures, and are not exactly correct except under "standard" atmospheric conditions. For example, an altimeter will usually read lower than actual altitude in summer and higher in winter. This is due to atmospheric temperature and not to any error in the instrument.

Altimeters are also subject to errors due to change in barometric pressure during a flight. If the barometer falls, the altimeter will read high, while if it rises it will read low. This characteristic may be turned to good account and the instrument used as a weather guide.

Most altimeters are now manufactured with a barometric scale in addition to the altitude scale which increases their usefulness considerably. A pilot may secure information regarding the barometric reading at the field of his destination and then, on taking off, set the zero of his altimeter dial to correspond to the barometric pressure of his destination. The altimeter will then read correct altitudes above the field for which the pilot is headed. An altimeter is shown in Fig. 8.



FIG. 8.—Altimeter. (*Consolidated Instrument Co.*)

Air-speed Indicator.—The air-speed indicator (Fig. 9) shows the speed of the aircraft in relation to the air surrounding it in flight. This bears no direct relation to its speed over the ground, due to the fact that there is no way to compensate for the speed and direction of the air through which it is moving except by the use of additional instruments.

An air-speed indicator is a sensitive pressure gage which is adapted to indicate in terms of air speed (at sea level) by the use of a pitot-static head which accurately resolves the air speed into its equivalent pressure. Due to their inherent disadvantages, venturi tubes are seldom used with air-speed indicators. The pitot-static tube, Fig. 10, requires no calibration and may be used interchangeably with any air-speed indicator of the pressure type.

The use of a reliable air-speed indicator is urged by every pilot of wide experience. It gives a plane a safety factor which cannot be obtained by any structural feature. Every ship has a certain safe flying range of speed, the lower extreme approaching the stalling point, and the higher extreme nearing the condition of a dangerously steep dive. The air speed for a given engine speed is, therefore, an index of the fore-and-aft angle of the airplane. Its use greatly facilitates the maintenance of the correct longitudinal altitude, particularly under conditions of poor visibility.



FIG. 9.—Air-speed indicator.
(*Aircraft Control Co.*)

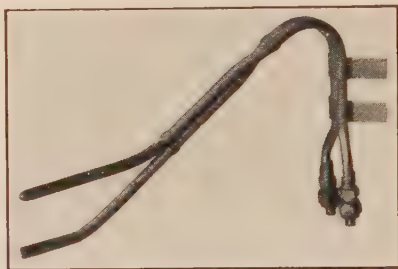


FIG. 10.—Pitot-static tube.

Persons installing air-speed indicators should be cautioned not to blow into the instrument to see the hand move. The pressures on which they operate are so slight that treatment of this kind is almost sure to blow up the diaphragm and completely ruin the instrument. In connecting the instrument to the pitot-static tube, care should be taken that no traps are formed in the tubing which will permit water to remain in the tube. It is recommended that drain Tee's be installed at the lowest point in each tube which should be opened frequently to release any accumulation of moisture in the tubing. This is very important.

Magnetic Compass.—The compass is the most necessary instrument for flight over water or unfamiliar country, or in fogs, clouds, or at

night. It is essential for the pilot to understand, however, that there are certain conditions under which the compass must be supplemented by a turn indicator. A typical modern compass is shown in Fig. 11.

The function of a compass is the indication of the direction in which the airplane is heading when flying on a straight course. It does not indicate correctly on turns which are fast enough to require an appre-



FIG. 11.—Late design of magnetic compass with correction card always in view.

iable banking of the airplane. The errors increase rapidly with the increase in the banking angle, a bank of about 20 degrees being sufficient to completely destroy the function of the compass. This condition is inherent in any compass depending upon the earth's magnetic field for its directive effect and upon gravity for its stabilization.

Because of the errors introduced in turning, the compass cannot be used to hold the plane on a straight course unless the ground can be watched for a directional reference. When the ground is not visible, a turn indicator must be used to maintain straight flight. As long as the

airplane does not turn, its direction will be accurately indicated by the compass. It must not be assumed, however, that the use of a compass is greatly limited. In service one is not concerned with the compass reading except when flying straight, and under this condition the instrument is entirely dependable.

A compass should be mounted where it can be read easily, and located as far as possible from iron and steel parts. If possible it should be placed on the fore-and-aft center line of the airplane. Where two compasses are mounted on the same ship they should be located at least 2 feet apart.

To completely compensate a compass is often a long and rather tedious task, and is seldom attempted except on aircraft undertaking very long flights. It is ordinarily sufficient to adjust the compass to within 1 or 2 degrees of the true magnetic heading on the cardinal points (North, East, South, and West), and to make a note of the errors on the other headings, for which allowance can be made in setting the course. This adjustment is not difficult and is quickly made.

Various means may be employed for determining the true magnetic directions, depending upon local conditions and type of plane. A simple method consists in tying a long piece of string to some point on the plane from which an accurate fore-and-aft or lateral sight can be made, and hanging a small compass from this in such a way that the string passes over its pivot. By turning the plane and sighting along the string, any desired positions can be obtained.

Whatever method is used for determining directions, the following procedure is recommended for compensating compasses using loose compensating magnets. For directions for using Titterington Compensator see page 383.

Head the plane approximately north. Note true direction. Compare indicated direction. If they do not agree, place compensating magnets in the athwart-ship magnet carrier until the compass indicates correctly. Next head the plane approximately east, and compare readings. If not in agreement, place magnets in fore-and-aft tube until the compass indicates correctly. Repeat on south and west headings. If compensation is required on either of these headings it will of course throw out the compass on the opposite heading. Only half the error, therefore, should be removed. This will leave the errors at opposite headings approximately equal. Now swing the ship to at

least four intermediate headings and note the errors. Enter these figures on a card and attach it to the plane near the compass.

TYPICAL CHART OF COMPASS CORRECTION

True heading, degrees	Indicated heading, degrees
0	0
45	48
90	90
135	133
180	180
225	228
270	270
315	312

A compass should require little attention beyond periodic rechecking of its compensation. Bubbles, which appear occasionally in some type of compasses, are easily removed as follows: Remove and invert compass. Remove filling screw and manipulate compass until bubble comes just below filling hole. Drop in kerosene or Varnolene with a medicine dropper or fountain pen filler until it overflows. Replace filling screw and reinstall compass.

Titterington Micrometer Compass Compensator.—The Titterington Micrometer Compensator is completely self-contained and eliminates the loose magnets which have heretofore provided the only satisfactory means of compensating a compass.

To secure any required amount of magnetic force with the micrometer compensator, it is simply necessary to turn the screws which are exposed just between the letters *EW* and *NS* (Fig. 12). The upper screw introduces magnetism for correcting the compass on east and west headings, and corresponds to the fore-and-aft tube of the old loose-magnet compensator. The lower screw is used for correcting the compass on north and south headings, and corresponds to the athwart-ship tube of the old compensator.

To compensate a compass with the Titterington Micrometer Compensator, follow these instructions:

Determine directions by means of a magnetic compass suspended from a wing tip, or by sighting with a surveyor's transit.

Head the airplane due north (magnetic). If compass does not read *N*, turn lower compensator screw until compass does read *N*. Use special screwdriver furnished with compass or any non-magnetic metal strip.

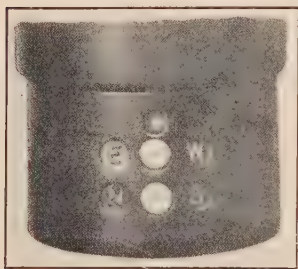


FIG. 12.—Compensating screws for compass in Fig. 11.

Next head due west. If compass does not read *W*, turn upper compensator screw until compass does read *W*. Next head due south. If compass does not read *S*, turn lower compensator screw to take out *half* the error. Next head due east. If compass does not read *E*, turn upper compensator screw to take out *half* the error.

Now head the airplane successively *N*, 330, 300, *W*, 240, 210, *S*, 150, 120, *E*, 60 and 30 degrees, noting the compass indication on each heading on a correction chart.

The following technical explanation is added for the benefit of those who may be interested.

The Titterington Micrometer Compensator accomplishes what has long been the dream of physicists and compass makers; in effect, a

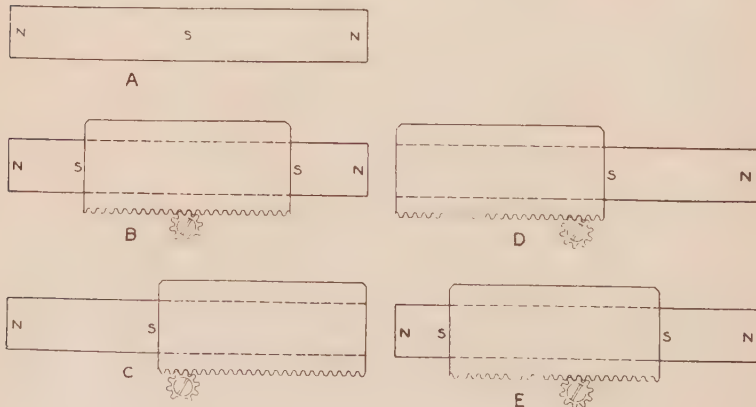


FIG. 13.—Titterington compensating magnets adjustment.

reversible magnet. This has been achieved by making a permanent magnet with north poles at each end and a south pole in the center, as at *A*, Fig. 13.

The effective external field of this magnet is zero, as it is the equivalent of two magnets which just balance each other. Around this special double magnet is a soft iron tube, half the length of the magnet, which acts as a magnetic shield. When placed in the middle of the magnet, as at *B*, the tube shields one-half of each end of the magnet leaving the effective external field still at zero.

By turning the screw which is geared to the tube, the latter is moved toward one end of the magnet, as in *C*. The tube is now shielding one-half of the double magnet leaving the external field of the other half fully effective. The result is a N-S magnet of maximum strength. Moving the tube to the other end, see *D*, leaves the external field of an S-N magnet of maximum strength. Stopping the tube at any intermediate point, as at *E*, shields each end partially and leaves an effective external field of any required strength in either direction.

The Titterington Micrometer Compensator contains two such center-pole magnets, one (the upper) being fore-and-aft, and the other (the lower) being athwart ship. As used on the Pioneer Earth Inductor Compass, for which this type of compensator was originally developed, only one magnet is required, the entire compensator being rotated to place the correcting magnet in line with the resultant disturbing force. Another type of compass with lamp for indirect lighting through a glass rod is shown in Fig. 26.

Bank and Turn Indicator.—The turn indicator, as now manufactured, is made exclusively by the Pioneer Instrument Company of Brooklyn, N. Y. under their own patents and those of the Sperry Gyroscope Company, are shown in Fig. 14. The Pioneer Turn Indicator is used for

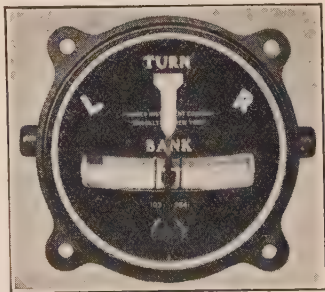


FIG. 14.—Bank and turn indicator.

controlling the flight of aircraft under conditions of poor visibility, or when for any reason it is desirable to eliminate yawing or turning. Used in conjunction with the bank indicator which is built into the dial of all turn indicators, the pilot is able to maintain a laterally level attitude while flying straight and to bank at the proper angle when turning.

A compass by itself is of little value when flying in clouds or at night as it is practically impossible for a pilot to hold his ship on a straight course, and a compass will only indicate correctly during straight flights or on very slow turns. By using a turn indicator, which shows the slightest divergence from straight flight, the pilot avoids turning, and his compass will function properly. A straight course is maintained by steering so as to keep the indicator in a central position. By keeping the inclinometer ball in the center of its tube the aircraft is held laterally level when flying straight, or on the correct bank when turning.

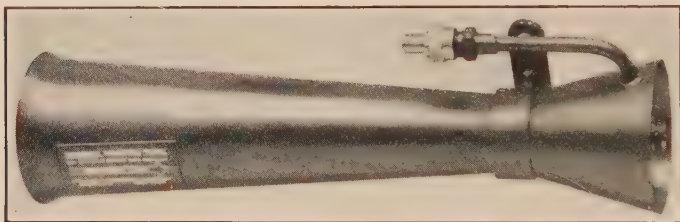


FIG. 15.—Venturi tube.

The sensitive element of the turn-indicating mechanism is a small air-driven gyroscope, operated by the suction secured from a venturi tube Fig. 15. The gyro is mounted in such a way that it reacts only to motion about a vertical axis, being unaffected by rolling or pitching.

The installation of the turn indicator is not difficult. The venturi tube should be mounted on the side or top of the fuselage or on a strut, as close as possible to the instrument board. It must be placed in a position where it receives an unobstructed flow of air. Mount the tube so that the small cone points forward.

Pitch and Bank Indicator.—The pitch and bank indicator, or lateral and longitudinal inclinometer, Fig. 16, is used for the purpose of indicating lateral and longitudinal stability of the airplane. The instrument consists of two tubes filled with liquid placed at right angles to each other and fore-and-aft and lateral in relation to the plane. When the plane is in normal flight, the air bubbles are in the center of the tubes. When the plane is either laterally or longitudinally out of position the bubble indicates the extent of its divergence.

Rate of Climb Indicator.—The rate of climb indicator shows the *rate* at which an airplane is climbing or descending. It does not indicate

the angle of the airplane in respect to the horizontal, as do gyro and bubble inclinometers, but is operated directly by the rate of change of atmospheric pressure which accompanies change of altitude. This instrument has many uses, but it is most useful in fog, clouds, and at night, or whenever an obscured horizon makes longitudinal control difficult.

The rate of climb indicator is a sensitive differential pressure gage. It consists of a metal diaphragm, one side of which is directly connected to the atmosphere, and the other side is connected to the atmosphere

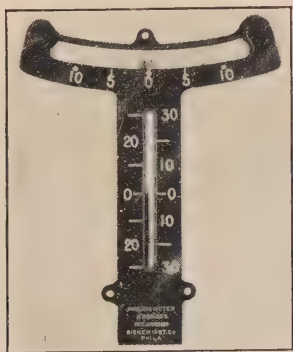


FIG. 16.—Rieker inclinometer.

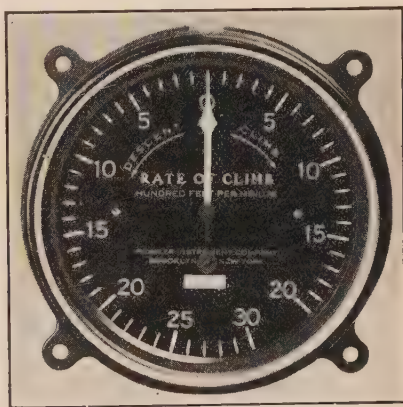


FIG. 17.—Rate-of-climb indicator.

through a capillary leak tube. Atmospheric pressure varies in a known relation to altitude. As the altitude increases, the pressure decreases. This pressure decrease is transmitted instantly to one side of the diaphragm, and slowly to the other side through the capillary tube. The difference in pressure between the two sides causes the diaphragm to expand or contract, and the movement is transmitted to the hand. The amount of this movement is proportional to the rate of change of altitude.

This instrument, illustrated in Fig. 17, is made exclusively by the Pioneer Instrument Company, of Brooklyn, N. Y.

Air-distance Recorder.—The air-distance recorder registers the air mileage of the airplane in flight. The instrument consists of two units; the transmitter and the recorder. The transmitter unit (Fig. 18) is

attached to a strut in a manner similar to a pitot tube and connected to the indicator by means of a copper tube. The recording unit (Fig. 19) is on the instrument board. A small propeller in the transmitter revolves as the plane goes forward and actuates a valve once a mile which admits vacuum, created by a small but powerful venturi tube to the recorder, adding 1 mile to the recorded distance.

This instrument is valuable in checking the performance of planes. It enables the operator of the airplane to determine the life of the

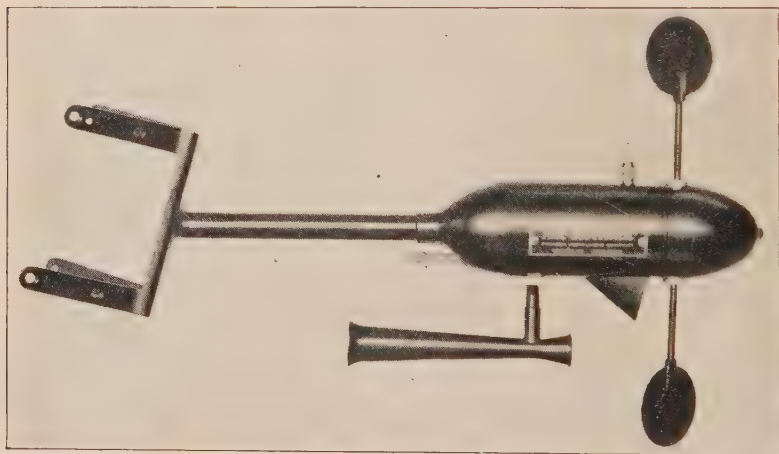


FIG. 18.—Air-distance recorder—transmitter unit.

engine, check the oil and fuel consumption, and give other valuable information on a basis of air miles flown rather than flight hours as is usually the practice.

Earth-inductor Compass.—The Pioneer Earth Inductor Compass is a remote indicator of direction. It is related to the ordinary magnetic compass only in its use of the earth's magnetic lines as a directive base.

There is no physical similarity between the two types of compass. The earth-inductor compass comprises three principal units. That which reacts with the earth's field and therefore corresponds to the magnets of an ordinary compass, is the inductor generator. This resembles an ordinary electric generator, except that it has no artificial

field. It has an armature, commutator and brushes, and produces electric potential by reaction with the earth's field. As in the case of any electric generator, the potential depends upon the angle between the brushes and the field. In the earth-inductor generator, the brushes



FIG. 19.—Air-distance recorder—recorder unit.

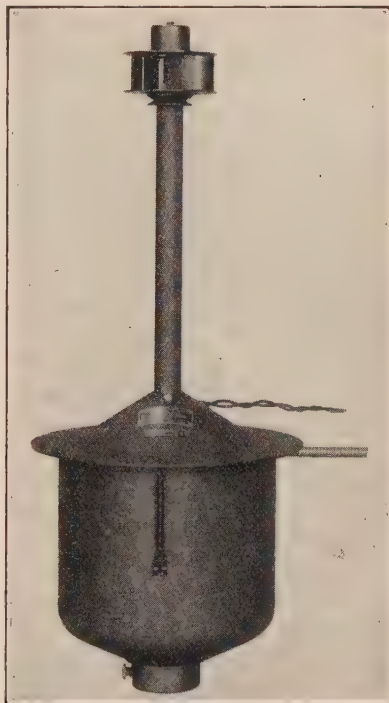


FIG. 20.—Generator of "Pioneer" earth inductor compass.

may be oriented about a vertical axis so that they may be set in any angular relation to the fore-and-aft line of the airplane. They may therefore be turned in relation to the earth's field, either independently or with the airplane. As in any generator, turning the brushes in relation to the field discloses two positions of maximum potential and two positions of zero potential. In the earth-inductor compass, use is

made of one of these positions of no potential. The generating unit is shown in Fig. 20.

The second unit is the direction controller (Fig. 21). This carries a dial similar to an ordinary compass card and has a crank by which this dial may be turned to any position. There is a mechanical connection between the controller dial and the brushes of the generator so that the angular position of the brushes is indicated upon the controller dial.

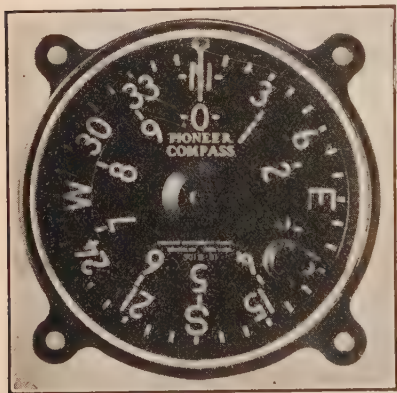


FIG. 21.—Controller of "Pioneer" earth inductor compass.



FIG. 22.—Indicator for "Pioneer" earth inductor compass.

The third unit of the compass, the steering indicator (Fig. 22), is a sensitive zero-center galvanometer, the dial of which is marked LEFT and RIGHT. The indicator is electrically connected to the brushes.

When the compass is installed, the connection between the controller and the generator is made such that when the airplane is headed in the direction indicated on the controller, the brushes will be in a position of zero potential. The steering-indicator hand will therefore remain in the center of the dial. If the airplane is turned to the right, the generator brushes will be turned in relation to the earth's field and the generator will produce electricity of the proper sign to cause the hand of the steering indicator to move to the right, showing the pilot that the airplane has turned to the right. Turning the airplane to the left will put the generator brushes into such position that electricity of the

opposite sign is generated, causing the steering-indicator hand to move to the left.

As the compass is ordinarily used, the desired heading is set upon the dial of the controller and the airplane is then turned until the steering-indicator hand comes to zero. Turns to the right or left away from this heading will cause the hand to move right or left. When it is desired to change heading, the controller dial is cranked to a new position and the airplane again turned to bring the steering-indicator hand to zero.

The earth-inductor compass offers many advantages over the ordinary magnetic compass, particularly for use on aircraft. It is much easier to follow the hand of the steering indicator than it is to keep a certain mark on a swaying compass card opposite the lubber line. The outstanding advantage, however, is the disassociation of the direction-responsive element and the direction-indicating units. In the ordinary magnetic compass, these cannot be separated and in order that the pilot may see his compass, it is frequently necessary to place it in a position where it is subject to strong local magnetic fields. With the inductor compass, on the other hand, the generator may be placed in a position which is practically free from magnetic disturbance, while the steering indicator is placed in the best position for observation by the pilot. The controller may be operated either by the pilot or by a navigator.

The Pioneer Earth Inductor Compass is the invention of the late Morris M. Titterington, formerly chief engineer of the Pioneer Instrument Company.

It was used by the U. S. Army on their Round-the-World and Pan-American flights, on Commander Rodgers' Hawaiian flight, Commander Byrd's North Pole flight, on the Trans-Atlantic flights of Lindbergh, Chamberlin, and Byrd, and on the flight of Brock and Schlee from New York to Tokio.

Speed and Drift Indicator.—A drift indicator (Fig. 23) is a necessary auxiliary to a compass, if accurate aerial navigation is to be accomplished. As is well known, an airplane may be headed in one direction yet follow a course in another direction. The difference between *heading* and *course* is the *drift angle*. This is illustrated diagrammatically in the diagram (Fig. 24). The airplane *A* is headed in the direction *H*, but because of the side wind *W*, actually travels toward *C*. The angle *D* is the drift. In order to "make good" the desired course, it is impera-

tive that the pilot (or navigator) know the drift angle so that he may calculate the heading and that the airplane be steered accordingly.

The only practical way of ascertaining the drift is by observation of the ground, and a drift indicator, or drift-angle meter as the instrument is sometimes called, is used for this purpose.

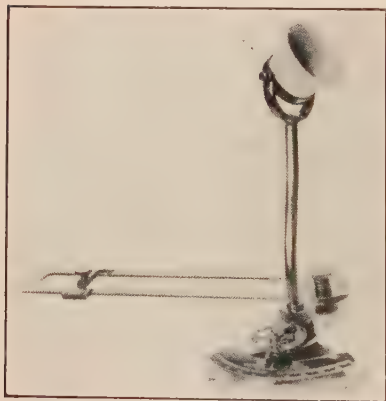


FIG. 23.—Drift indicator.

This instrument may be mounted anywhere on an airplane where it affords an unobstructed view downward (vertically if possible, but at an angle if more convenient) and where it may be conveniently observed and manipulated by the navigator. The instrument is supported by a mounting bracket from which it may be quickly removed. It is sometimes advisable to install two or more brackets and to transfer the instrument from one

to the other, according to the direction of drift or the convenience of the navigator. The mounting bracket must be installed with its center line either fore-and-aft or athwartship. Any error in its location will cause a corresponding error in drift readings.

To obtain the drift angle with the speed and drift indicator, first make fast the support for the eyepiece in a position which will be convenient for the user and also allow him to make his observation properly. It is not necessary that the eyepiece be directly over the wire. The

operator then sights through the eyepiece at the drift wire and the ground below. The vane is now rotated so that objects on the ground or sea appear to travel along the drift wire. This means that the drift wire is now in line with the course being made good in respect to the ground.

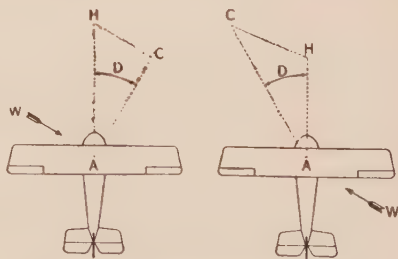


FIG. 24.—Use of drift indicator.

The drift angle, or angle between the heading of the plane and the course being made good, can now be read from the scale.

To obtain the ground speed, the vane is left in position corresponding to the drift angle and the slider is moved along the vane until the cross-wire is at the figure corresponding to the altitude of the plane above the ground which it is flying over. The altitude of the country which the plane is flying over must be subtracted from the altitude of the plane above sea level to obtain the altitude of the plane above the ground. Looking through the eyepiece, the distance seen on the ground is that marked on the side of the vane—either $\frac{1}{10}$ mile, $\frac{4}{10}$ mile, or 1 mile. The scale which reads "1 mile for altitude in 1,000 feet" can also be used for " $\frac{1}{10}$ mile for altitude in 100 feet."

With a watch, the time of passage of an object from one wire to the other is noted, and reference to a table which is furnished with the instrument gives the corresponding speed in miles per hour. For example, let us assume it is desired to obtain the ground speed while flying at an altitude of 4,000 feet above the ground. First move the slider along the vane and set the cross-wire at the Fig. 24 which is on the scale marked " $\frac{4}{10}$ mile for altitude in 1,000 feet." Assume the stop watch shows the time of passage of an object on the ground between the fixed cross-wire and the movable cross-wire to be 12 seconds. Reference to the conversion table will quickly show the speed to be 120 miles per hour. But if the table is not at hand, simple arithmetic will do. The distance seen on the ground between the cross-wires was $\frac{4}{10}$ mile and the elapsed time 12 seconds. This is at the rate of 1 mile in 30 seconds, 2 miles per minute or 120 miles per hour.

Sextant or Octant.—Aerial navigation has developed the necessity for aircraft sextants similar to those used on sea-going vessels, and both sextants and octants have been developed for this purpose. The difference between a sextant and an octant is that the former has an arc of 60 degrees (one-sixth of a circle), while the octant has an arc of but 45 degrees (one-eighth of a circle). The problems involved in aerial navigation make necessary an instrument quite different from the standard nautical sextant.

It must be light weight for ease of handling and must be equipped with an artificial horizon. It is used similarly to a nautical sextant, except that additional factors, such as altitude, etc., are introduced and must be corrected for. The use of these instruments is limited to per-

sons having a thorough knowledge of the science of navigation, as the problems involved are extremely scientific and exacting. An aircraft octant is shown in Fig. 25.

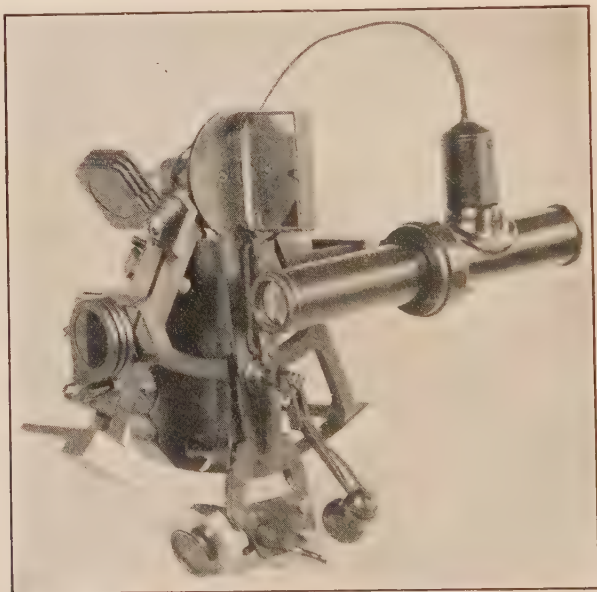


FIG. 25.—Aircraft octant.

Sun Compass.—The sun compass, an invention of A. H. Bumstead of the National Geographic Society, is intended primarily for use within the Arctic and Antarctic Circles where magnetic compasses are quite unreliable due to magnetic disturbances and deviations. The sun compass is entirely non-magnetic in principle. It operates in conjunction with a special 24-hour watch which has a “sun dial” instead of the usual watch hands. When this instrument is accurately attached on the fore-and-aft axis of the airplane it is possible to determine the direction of flight by rotating the mechanism until the shadow of the “sun-dial arm” falls between the vertical lines of the screen opposite.

This instrument can only be used when the sun is available but is by far the most accurate type of compass for Polar exploration. It has been used successfully by Captain Hubert Wilkins and Commander Richard E. Byrd on their aerial explorations to the Poles.

INSTRUMENT-BOARD LIGHTING

Until recently instrument boards have been illuminated with lamps similar to those used on automobiles before the advent of indirect lighting. Several methods of indirect illumination for airplane instrument boards have now been developed and are in general use.

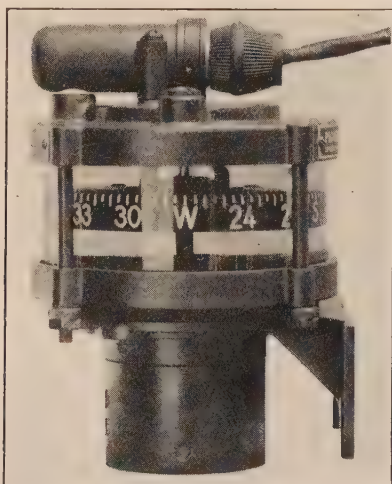


FIG. 26.—Compass with indirect light above.

It is recommended that the lighting of instrument boards be controlled by a rheostat instead of by an on-and-off switch which was formerly standard practice. The rheostat permits the pilot to control the illumination, to conform to the light conditions under which he is flying, and permits him to use his own judgement as to the best illumination to be used. As darkness approaches it is necessary to have the illumination more intense than when the eyes have become accustomed to the dark. The ideal illumination of the board is such

that the instruments are just visible but not bright enough to blind the pilot and prevent him from seeing clearly and quickly when he looks up from the cockpit to the air through which he is flying.

A compass with indirect lighting through a glass rod is shown in Fig. 26. The instrument board in Fig. 1 is also lighted by a new, indirect method.

ELECTRIC WIRING FOR AIRPLANES

The electric wiring on airplanes should receive careful attention both for efficiency and safety. Wires should be of ample size to carry the current in all cases, particularly the landing lights which require about 35 amperes, usually at 12 volts although some use 6-volt systems. Nothing smaller than a No. 8 wire should be used for landing lights.

For running lights on the wings and tail and for the navigation lights on the instrument board use a No. 18 or larger. The running lights are 21 candlepower and the lights on the instrument boards 4 candlepower.

SECTION IX

AIRPLANE CONSTRUCTION

Airplane construction is changing in many ways. The use of metal has increased to the point where wood has almost disappeared in fuselage construction; two exceptions being shown later. Wing beams continue to be made of wood in many cases because the limited production makes it more economical to use wood than metal. Some of the larger builders, however, are building wing beams of metal shapes, as will be seen later.

Steel tubing can be welded into almost any desired construction and is used in nearly all commercial planes. It is almost universal for fuselage construction and appears to a considerable extent in wings, ailerons, rudders, fins, and landing gears. Advocates of the use of the lighter metals claim that it is difficult to control the expansion and contraction of welded joints so as to maintain correct alignment when removed from the welding fixtures. The almost universal use of this construction, however, hardly bears out this contention. The use of duralumin or of the strong aluminum alloys involves the use of riveted joints, but these have been worked out so ingeniously that they afford opportunities for excellent construction with great flexibility. This is notably true of the Eureka section of the Glenn L. Martin Company as shown in detail elsewhere.

Although wooden construction still has many advocates for some parts, and plywood lends itself to a variety of applications, the tendency seems to be toward metal; a few even using it for wing covering. Cloth, however, continues to be favorite covering for wings and other surfaces although Fokker uses plywood for wing covering. Wing ribs are made of both wood and metal and in various forms.

New designs and methods have reduced manufacturing costs to a marked degree. Progressive assembly is now found in nearly all airplane plants, this being taken from the automobile shop and helping to produce a better plane at lower cost.

The wiring of an airplane for electric lights and radio is a problem unknown to the earlier builders. Running lights are a necessity for all planes flying at night and, unless a well-lighted landing field is assured, ample landing lights are also necessary. These lights make it necessary to know the proper sizes of wire to use for different conditions. Details of the lights are given in Sec. VII.

The introduction of radio adds numerous complications, including the shielding of the radio apparatus from the effect of the ignition spark and other disturbances such as the charging generator and the vibration or rubbing contacts between metal parts. Each ignition discharge creates an electromagnetic field which links the antenna and wiring of the radio set and causes a disturbance that may drown out the other signals. Among the methods that have been worked out to overcome these disturbances is one known as the Belden harness that, in effect, encloses the alternating magnetic field in every direction. This shielding includes both the low-tension and the high-tension circuits, the latter shielding having been found to be a fire preventative as well. For testing the efficiency of the shielding the Belding Company suggest the following procedure, bearing in mind that the ignition disturbance in a shielded plane should not exceed a low hum in the head phones, similar to a weak but readable telegraphic signal:

Both the receiver and transmitter of the radio set should be completely installed and connected up.

The airplane should be in flight, the engine running at cruising speed.

The first stage of audio amplification on a standard superheterodyne receiver should be used.

The receiver should be tuned, so that an incoming signal will produce the greatest effect in the head phones.

The main line switch or circuit breaker should be in the "On" position.

Both ignition switches should be on.

All other electrical equipment of the airplane should be operating.

The following tabulation summarizes the causes of disturbance and the methods of eliminating them:

Cause of disturbance	Method of elimination
(a) Ignition.....	Shielding and bonding system and all circuits coupled either magnetically or electrostatically to it

Cause of disturbance	Method of elimination
(b) Charging generator.....	Shielding and bonding wires and parts of system from generator to storage battery to radio set
(c) Vibrating or rubbing contacts between metal parts.	Inserting an insulator between the part, or Bonding them with a metal strip at points of contact (This method is not suitable when applied to brace wires where there is danger of injuring the wire in soldering)

CURRENT CARRYING CAPACITIES OF AIRCRAFT COPPER WIRES

A. W. G. or B. & S. gage	Diameter of solid wire, mils	Area, circular mils	Varnished cambric insulation, amperes	Feet per pound
18	40.3	1,624	5	203.4
16	50.8	2,583	10	127.9
14	64.1	4,107	20	80.45
12	80.8	6,530	25	50.58
10	101.9	10,380	30	31.82
8	128.5	16,510	50	20.01
6	162.0	26,250	70	12.58
5	181.9	33,100	80	9.98
4	204.3	41,740	90	7.91
3	229.4	52,630	100	6.27
2	257.6	66,370	125	4.97
1	289.3	83,690	150	3.95
0	325.0	105,500	200	3.13

RADIO IN AIRCRAFT

That radio is to play an important part in aviation seems assured. Both as a means of communicating with ground stations and as a guide in some such form as the so-called radio beacon, it seems destined to find a place in commercial, if not in private air transport.

Radio is, however, such a special subject and one which as yet has not entered largely into either commercial or private flying that it is only considered in connection with ignition in this edition. The necessity for shielding radio apparatus from the influences of the magneto and the ignition wiring has been mentioned briefly on the preceeding pages. Being a highly specialized subject and one that does not, as yet, affect the operation of the average plane, its consideration is left for future editions.

METAL PLANE CONSTRUCTION

The best-known plane of all-metal construction is the Stout, as built by the Ford Motor Co. in Dearborn, Mich. With the exception of the

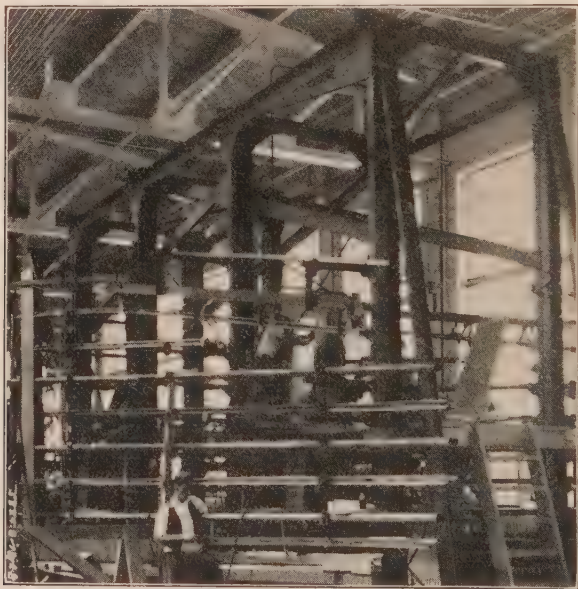


FIG. 1.—Wing tips assembly jig for Ford planes.

engine mount and the landing gear, the entire plane is built of the strong aluminum alloys, commonly but frequently incorrectly, known as "dural." The characteristics of these metals will be found in Sec. X.

The large assembly jig, shown in Fig. 1, is for the wing tips of the Ford plane. Right- and left-hand tips are assembled on opposite sides of the jig. This shows the main and auxiliary spars, made of riveted



FIG. 2.—Wing construction in Ford planes.

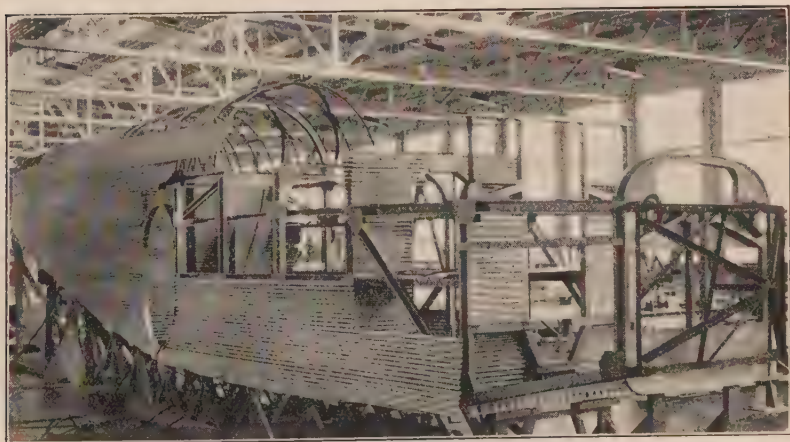


FIG. 3.—Corrugated covering for Ford plane.

elliptical tubing and of built-up beams. The man in the foreground is putting rib trussing between the spars while the men on the other side are about to apply a sheet of corrugated metal that forms the skin, or

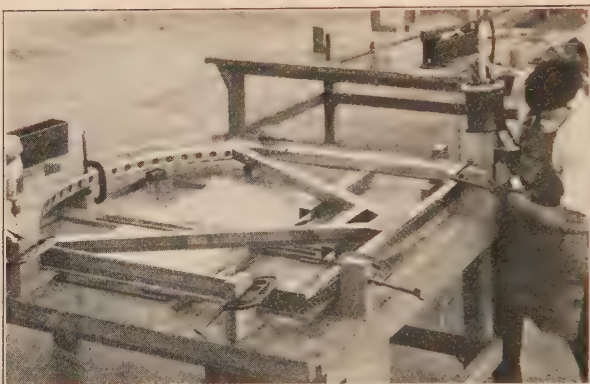


FIG. 4.—Frame or bulkhead assembly of Ford plane.

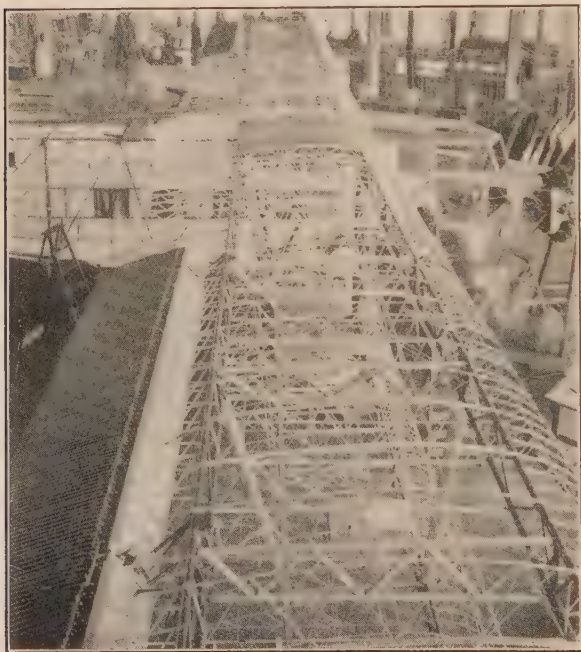


FIG. 5.—Upper wing and ailerons. (*Boeing.*)

wing covering. The jig is of steel and holds the parts rigidly while they are being riveted into a complete unit.

The construction of the wings are clearly shown in Fig. 2. This is what is known as a cantilever wing and is built thick enough to enable sufficient strength to be built into the internal trusses so that no outside support such as struts or guy wires are needed. The way in which the various members inside the wing are built into a substantial truss, using riveted joints, can be readily seen. This is a thick-wing section

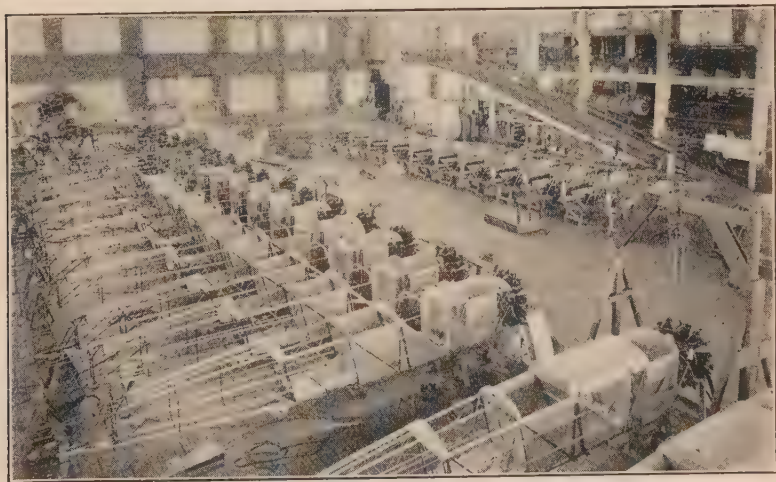


FIG. 6.—Assembling Boeing mail planes.

being approximately 32 inches at the thickest part. The section shown is fastened to the fuselage, or center section, by the bolts shown.

Still more of the construction of this large plane is shown in Fig. 3 where the fuselage has been built up of various shapes riveted together and the whole is being covered with the same corrugated metal as the wings.

Another example of aluminum-alloy construction methods shows how the various members are held in fixtures while being drilled and riveted. In Fig. 4 is one of the 13 bulkheads of a Ford plane. A pneumatic squeeze-riveter is used, which is noiseless. Great care is taken to have all rivets heat treated within an hour of being used, to



FIG. 7.—Fairchild wing of plywood and metal.

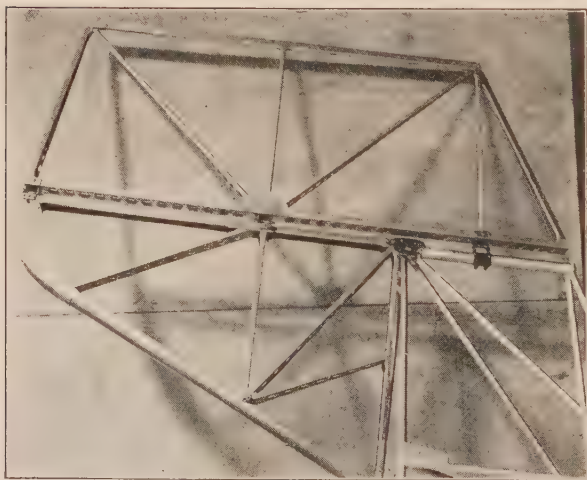


FIG. 8.—Uncovered fin and rudder. (*Fairchild.*)

prevent setting-up strains by working the metal after it has begun to harden.

Another excellent example of metal-wing construction is shown in Fig. 5 which is a lengthwise view of a large Boeing biplane. The entire

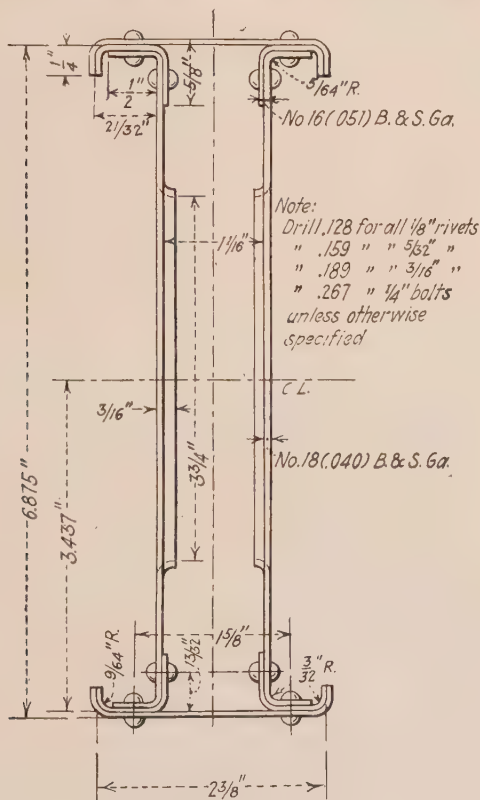


FIG. 9.—Section of Martin wing beam.

framework is of metal, the wing beams being built up of steel tubing and the ribs of aluminum alloy, rolled to special shapes designed to give the greatest stiffness and riveted into units for each assembly. The ailerons are entirely of metal, the covering being of corrugated

aluminum alloy sheet. It will be noted that the rib construction varies at different points, heavy straight ribs being used at frequent intervals to connect the front and rear wing beams, the lighter ribs giving the desired contour for the wing covering. This is a wing for a large three-motored transport for long distance passenger travel. An idea of the way in which planes are now being manufactured can be had from Fig. 6 which is an assembly line of Boeing planes for mail and similar service.

The combination of wooden-wing construction with metal ailerons is seen in Fig. 7 from the wing of a small Fairchild plane. Here the wing beams are built up with plywood sides, showing the use of plywood ribs and the way in which the leading edge of the wing ahead of the front beam is entirely of wood. The ailerons are of metal.

Metal construction of the fin and rudder is shown in Fig. 8 this being built up of aluminum alloy, formed in channel section and with riveted joints. The holes are flanged to add to the stiffness as well as to reduce weight.

A metal wing beam of strong aluminum alloy is shown in Fig. 9 as designed and used by the Glenn L. Martin Company. The main dimensions are given. Lightening holes $3\frac{3}{4}$ inches in diameter are punched in the side members at suitable intervals and flanged inward $\frac{3}{16}$ inch for stiffness. The thickness of the side members is 18 gage B & S or 0.040 inch, while the upper and lower members are 16 gage, or 0.051 inch.

In making up riveted members of aluminum alloy the practice is to drill the holes slightly larger than the rivets as follows;

For $\frac{1}{8}$ rivets drill holes, 0.128 inches.

For $\frac{5}{32}$ rivets drill holes, 0.159 inches.

For $\frac{3}{16}$ rivets drill holes, 0.189 inches.

For $\frac{1}{4}$ bolts, drill holes, 0.255 to 0.267 inches.

Eureka Strut Sections.—To facilitate the making of substantial joints with a riveted construction, using a strong aluminum alloy instead of steel tubing, the Glenn L. Martin Co. designed and used what is known as the Eureka section on a lot of planes built for the U. S. Navy in 1928. Details of this section are shown in Fig. 10 together with all essential dimensions. This, as will be seen, resembles the old Phoenix section used in steel columns many years ago, except that the center forms a square instead of a circle, as in the Phoenix. These

sections are readily built up from formed strips and can be spaced as desired so as to go over steel fittings of either plain sheets or built up to any desired shape and angle. Some of these connections are seen in later illustrations.

In the data with each illustration,

t = thickness of metal

I = moment of inertia

K = radius of gyration

A = area of section

DL = developed length of section

W = weight in pounds per inch of channel.

All rivets are spaced 3 inches apart in the same plane and staggered on the other side of the same channel, making the rivets $1\frac{1}{2}$ inches apart around the section.

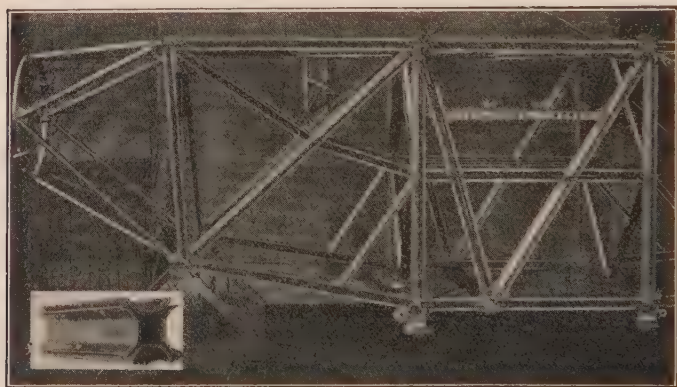


FIG. 11.—Eureka section and fuselage construction.

The appearance of the Glenn Martin Eureka section, and the facility with which it can be used to secure any desired construction is clearly seen in Fig. 11. A short piece of the built-up section is shown in the corner. By using steel fittings, either of forgings or built up of sheet steel, any sort of connection can be made with the desired amount of reinforcement, the angle making little difference. The way in which these sections are handled can be seen in Fig. 12 where a stiffening

section is being built up in a fixture mounted on a bench. This shows how the pieces are held, the kind of fittings used in the corners, and the

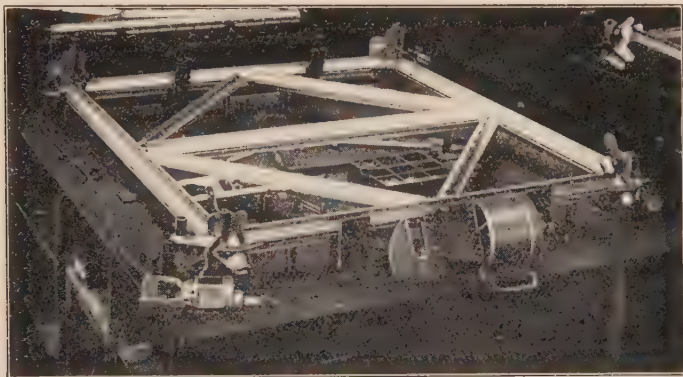


FIG. 12.—Assembling fixtures for fuselage bulk heads.



FIG. 13.—Steel tube fuselage joints.

drill and squeeze-riveter used in fastening the fittings in place. In contrast, the section of a somewhat similar fuselage, built up of welded steel tubing, is shown in Fig. 13.

Lockheed Construction.—The construction of the Lockheed fuselage is both unusual and interesting, being built up of veneer or plywood, molded and fastened to bulkheads, also of wood, making one form of what is known as monocoque construction. The method of laying the strips of Haskelite plywood on the form is shown in Fig. 14. After the strips of plywood have been built up to sufficient thickness on the form at the left, the form with the plywood is turned and placed in the large mold at the right and the cover bolted in place, the heavy

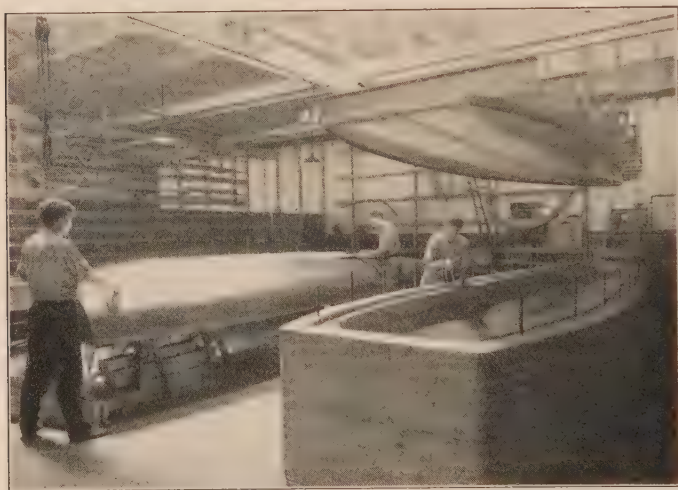


FIG. 14.—Lockheed fuselage mold.

I-beams across the top holding everything in place during the steaming and final forming of the half sheet that forms the outside of the fuselage. The fuselage in the foreground of Fig. 15 shows one half of the outside in place in the formed bulkheads. Beyond this both halves are shown in place, giving a good idea of the unusual construction. The smooth, stream-lined appearance of the finished plane is seen on page 18.

Another form of construction which is of interest though only used to a limited extent is shown in the fuselage of the International plane which was built up of a spruce frame-work in the form of a rectangular

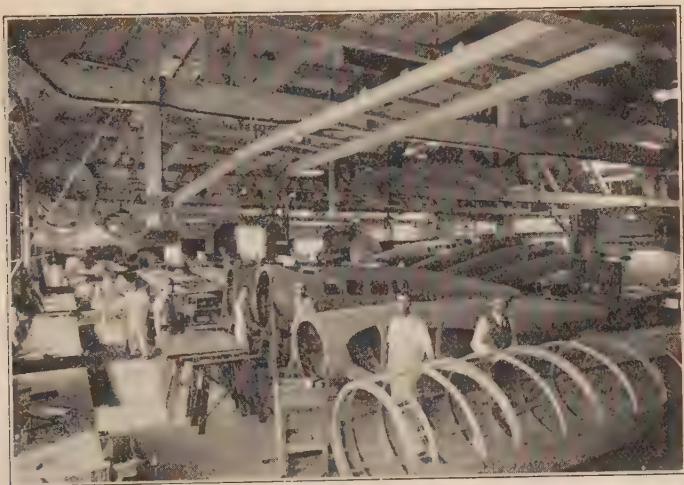


FIG. 15.—Fuselage assembly departments.



FIG. 16.—International truss and plywood fuselage.

truss, with the corners cut off as in Fig. 16. To this is added fairly heavy plywood sides, which add much to the strength of the construc-



FIG. 17.—Plywood wing beams and ribs.



FIG. 18.—Building Fokker wing beams.

tion. Wing beams and ribs are also built up of plywood as in Fig. 17, the top and bottom strips of the beams being of spruce. The wing ribs are cut out for lightness and have reinforcing strips top and bottom.

Another interesting wooden wing beam is from the Fokker plant, this being a cantilever wing, as in Fig. 18, supporting the whole load

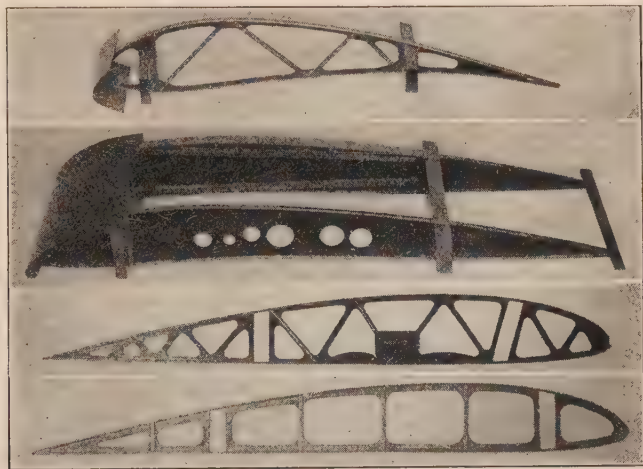


FIG. 19.—Four types of ply-wood wing ribs.



FIG. 20.—Covering wings at Chance Vought plant.

without external bracing. The wing covering of the Fokker is also plywood, thus adding to the strength of the wing by making it a kind of huge wooden tube.

A few examples of wing ribs built of plywood are shown in Fig. 19. These show varied ideas as to design and construction, but are all from actual planes in use.

Two views from the Chance Vought factory (Figs. 20 and 21) show how fabric is applied in the modern airplane plant. It is no longer a haphazard operation but is thoroughly organized and methodical.



FIG. 21.—Covering ailerons and stabilizers.

Folding Wings. —The housing of airplanes has been a problem since they first came into use and folding wings have been proposed by many in order to save room in storage. Comparatively few planes are, however, as yet, built in this way although there are two good examples in the Fairchild and the little Moth, the latter being popular in England and now under construction in this country. Both planes are shown with wings folded back in Figs. 22 and 23. The manner of locking the wing in position on the Fairchild is seen in Fig. 24. In most modern planes the wings are readily detachable by hinge fittings but they are not made to fold back.

Two other examples of metal construction are taken from the factory of the well-known Junkers plane, in Germany. A skeleton of the forward part of the riveted duralumin fuselage of the tri-motor plane is shown in Fig. 25. Here the members forming the structure of the fuselage are in place together with the extensions to which the wings are fastened. It will be noted that the mating edge is provided with

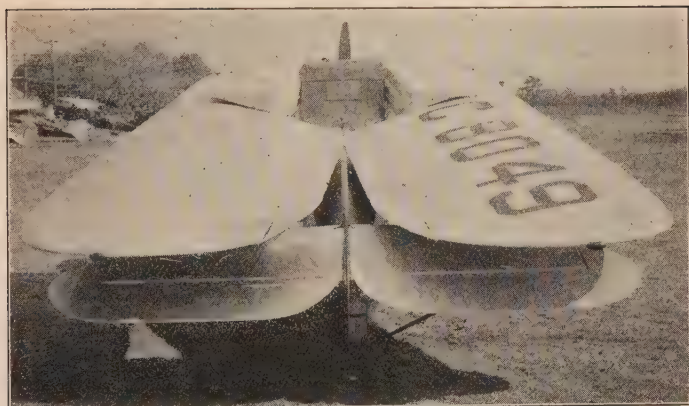


FIG. 22.—Rear view of a Fairchild with wings folded.

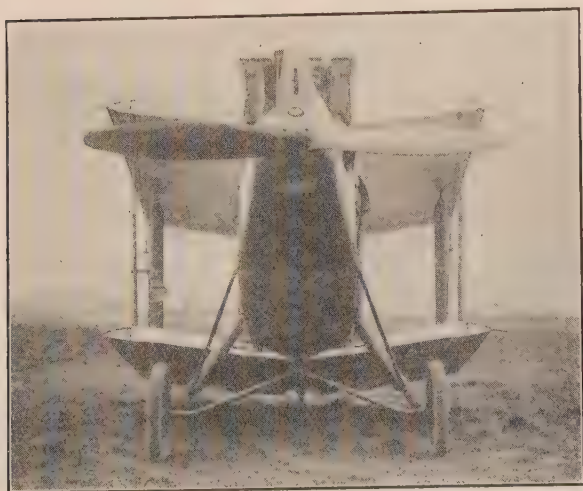


FIG. 23.—Front of Gipsy Moth with wings folded.



FIG. 24.—The lock of a Fairchild wing.

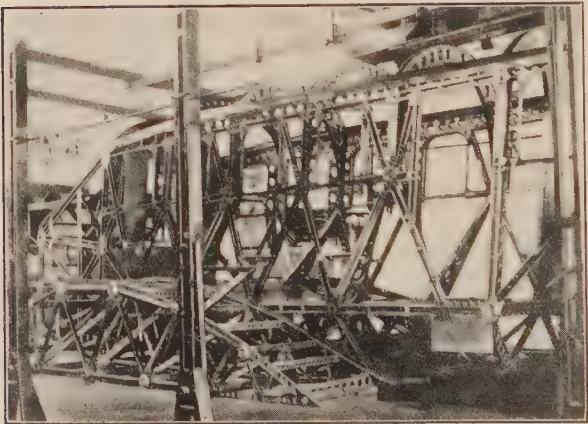


FIG. 25.—Riveted structure of Junker plane.

beveled ferrules at the ends of the horizontal tubes that form the bearing points for the truss. Mating ferrules on the end of the wing locate the parts accurately and allow them to be drawn together and held firmly by substantial through bolts. These locating ferrules are also shown



FIG. 26.—Showing how wings are attached.

in Fig. 26 where the wing section is in position for attaching to the fuselage. This also shows the nine ferrules and the way in which the corrugated duralumin is used to cover the plane.

WELDING

Both oxy-acetylene and electric welding are used in building and repairing the modern plane, where metal parts are to be joined. Its principal use is in connection with steel tubing and similar constructions. Several illustrations are given to show various applications of the way in which welding has become part of airplane building. In work of this kind, where so much depends upon the safety of the weld, only experienced men should be permitted to undertake even minor operations. A poor weld is not only liable to cause an accident but also throws an unwarranted stigma both on welding and on the airplane industry.

Without going into minute details of welding, it is in order to caution welders to wear proper goggles or other eye protection and to use the best welding material and apparatus obtainable for the purpose. Special welding rods are now available in cast iron, pure wrought iron, steel of various kinds, and alloys, Monel metal, bronze, and aluminum. These come in standard lengths of from 18 inches to 3 feet and in

various diameters. It is also available in coils and in strips of various widths.

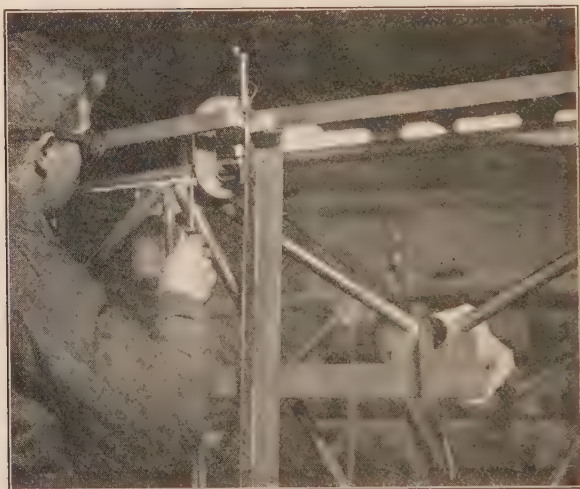


FIG. 27.—Welding joints held with C clamps.



FIG. 28.—Tail skid "stellited" to give longer life.

Before welding the lighter materials, such as aluminum alloys, it is well to secure the advice of the makers of the materials as well as of the welding apparatus. Duralumin for example, depends largely on heat

treating for its strength, and the intense heat of welding creates a problem that should be solved only by experts. Aluminum is easily welded but not duralumin or other strong aluminum alloys.

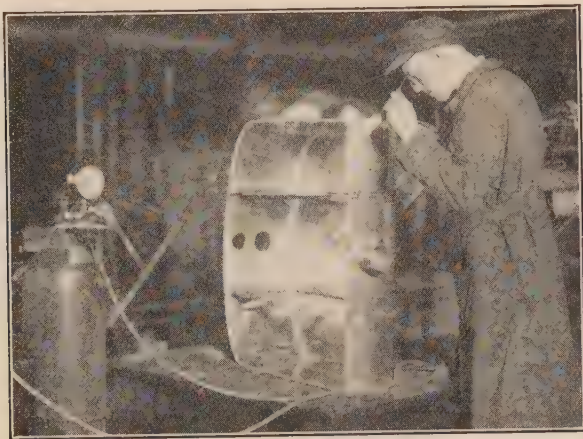


FIG. 29.—Welding a fuel tank.

Several examples of airplane welding are shown in Figs. 27, 28, and 29. Fig. 27 shows how parts to be welded can be held temporarily by using C-clamps and angle irons.



FIG. 30.—Examples of tube welding.

An excellent example of gas-welded joints is shown in Fig. 30, from the Fairchild factory. Welded fittings used in connection with the Glenn L. Martin Co. aluminum-alloy construction, using their Eureka section, are shown in Figs. 31 and 32. These show both the fittings

and the fixtures in which they were made. With these as a guide it is not difficult to design and build almost any type of fitting needed for special cases.

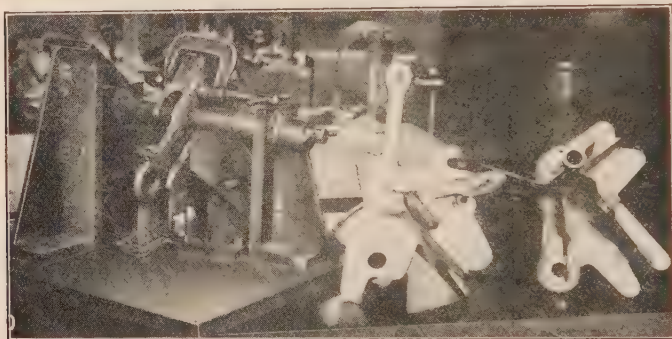


FIG. 31.—A Glenn Martin fitting and welding fixture.

Whenever it is necessary to make a part that cannot be fabricated economically from one piece of stock, welding is used to build up the desired structure. The illustration, Fig. 33, shows the way in which



FIG. 32.—Lower longeron fitting in fixture.

mud guards are built up in the Ford plant, using an oxy-acetylene torch in making the weld. After the parts are partially formed they are welded together, as shown, and then finally hammered into proper

shape. The mud guard shown is of sheet aluminum and requires considerable skill in welding satisfactorily.

Welding Aircraft Joints.—A committee of welding procedure appointed by the American Bureau of Welding prepared the following information for the welding of aircraft joints, using these methods in making the test joints for the Bureau of Standards. Both mild steel and chrome molybdenum steel were used both in tubing and in plates, but only one type of welding rod was used, this being U. S. Army



FIG. 33.—Welding a wheel guard.

specification No. 57-203-A, grade A for arc, and grade E for gas welding. With gages for oxygen showing working pressures up to 100 pounds, and for acetylene up to 30 pounds, tips are to be maintained in condition to produce the welding flames shown in *A* or *B*, Fig. 34. This illustration shows good and bad flames and the trouble in each case.

Tips should not be cleaned with any hard instrument, a wire either of soft brass or copper, or a piece of hard wood is best. The size of the tip must be inspected frequently and kept within half of a drill size of standard. Figures 35 to 41 show various types of welds and give all

necessary information concerning them. A convenient and fairly universal welding jig is shown in Fig. 42. Figure 43 shows limit gages for measuring butt and fillet welds and how the gages are used. Figure

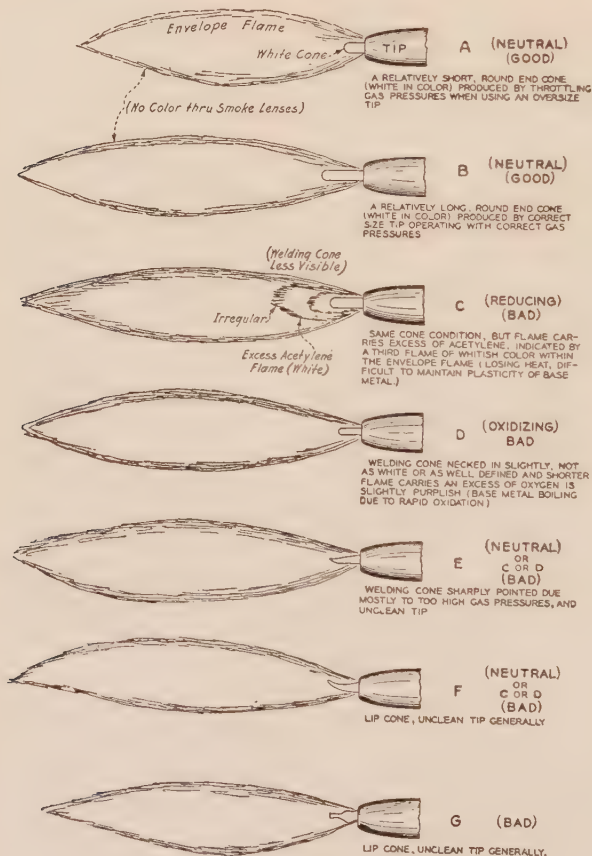


FIG. 34.—Welding flame characteristics.

44 shows what is known as forward and backward welding, being designated from the movement of the welding torch with relation to the metal being filled in. The backward method is recommended when

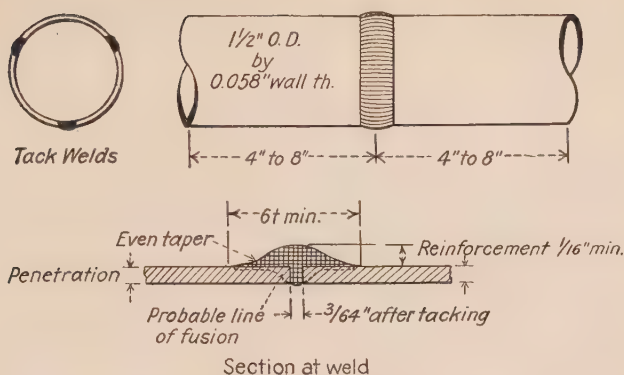


FIG. 35.—Open butt-weld test. Rotate tube while welding. Reinforcement $\frac{1}{16}$ to $\frac{1}{8}$ in. Width of weld to be eight times weld thickness.

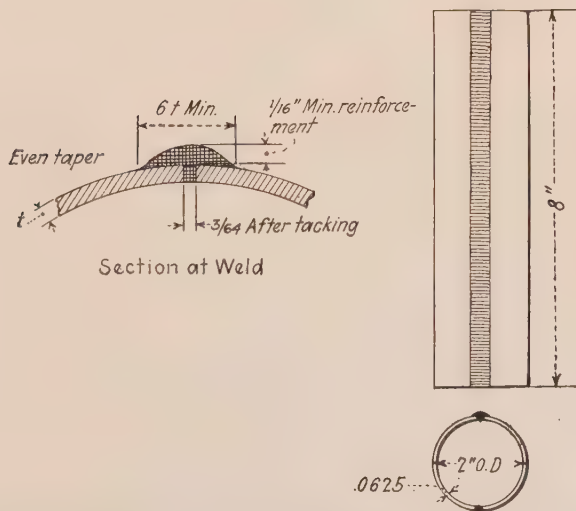


FIG. 36.—Position butt-weld test. Width of weld six times wall thickness.

Suggestions for Welding.—Where the proper jigs are used, it is seldom necessary or desirable to tack-weld tubing. Tubing is used in many other ways by the automotive industry. All-welded fuselages

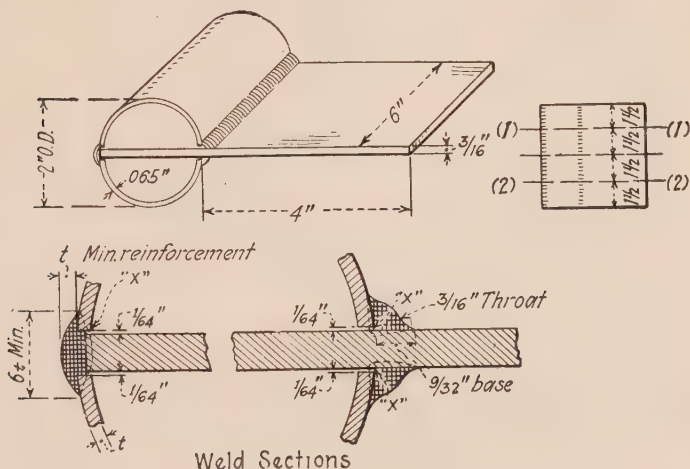


FIG. 39.—Reinforced welding test.

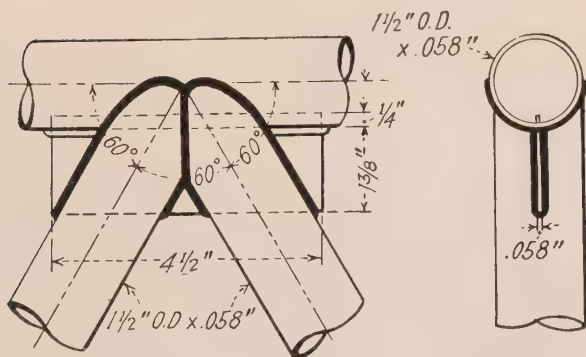


FIG. 40.—Angular welds with reinforcing plate.

for airplanes have become standard. For this purpose chrome-molybdenum and mild steel tubing is used and welds are usually made with either high test or mild steel welding rod.

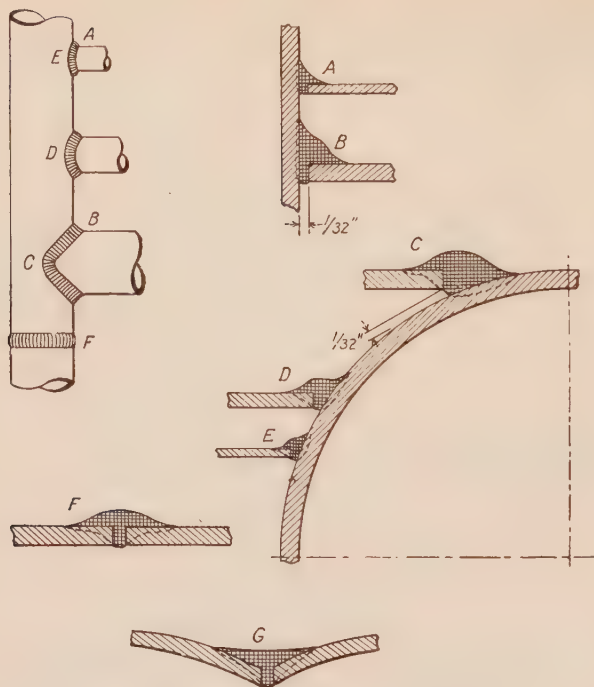


FIG. 41.—Various types of welded joints.

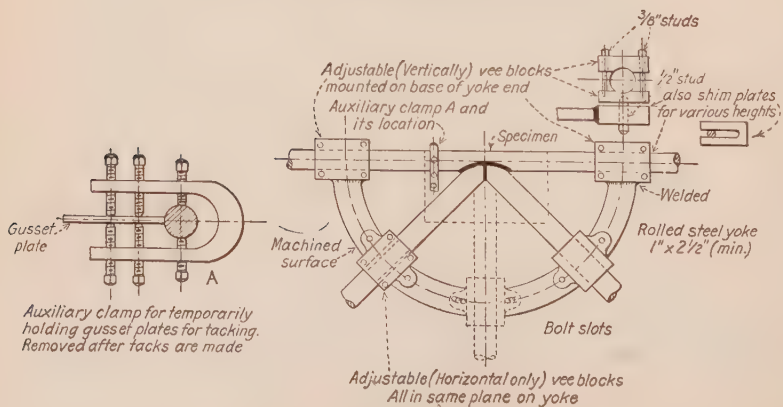


FIG. 42.—Universal welding jig.

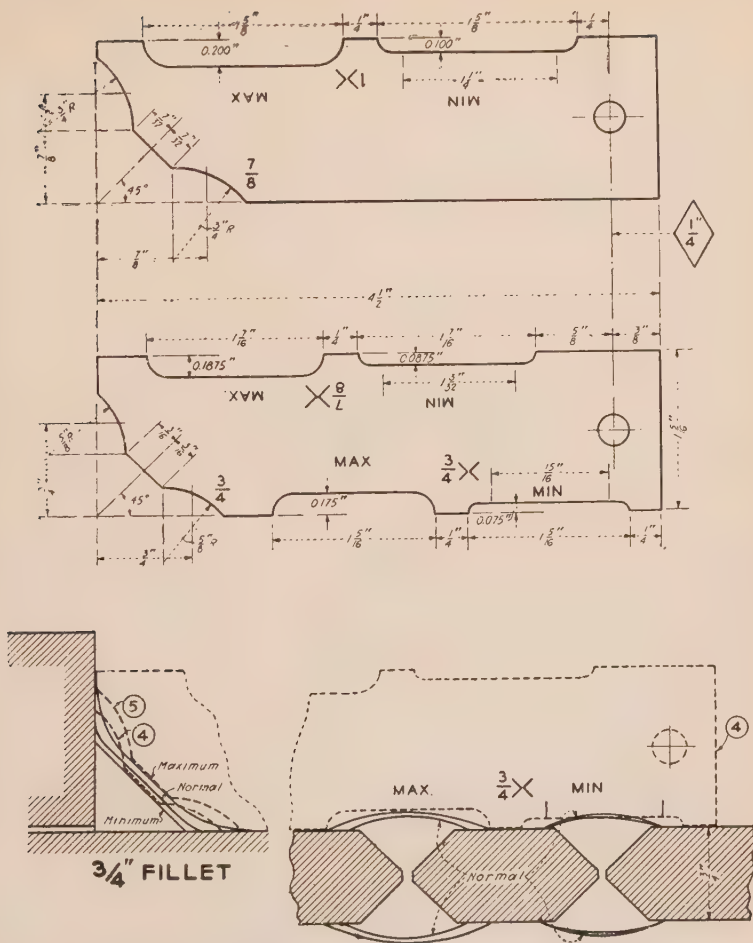


FIG. 43.—Gages for measuring butt and fillet welds and a sketch illustrating method of application to these gages.

Oxy-acetylene welding has simplified greatly the mechanical problems involved in aircraft construction. It eliminates fittings and other composite joints, and makes the fuselage frame itself, in fact and in action, one single unit of steel. The welded joint on planes of moderate size eliminates several hundred pounds of cast or forged fittings and gives a proportionate increase in pay load. The welded joint also gives remarkably high values in both tension and compression.

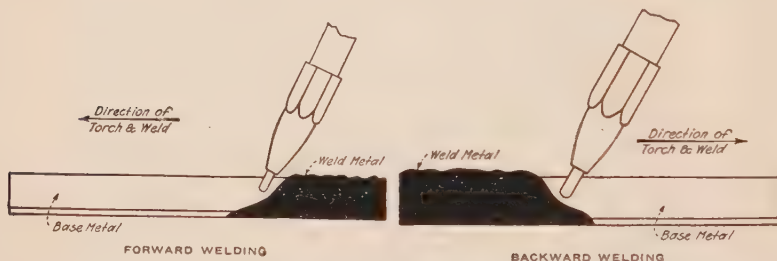


FIG. 44.—Methods of welding.

When welding is employed, the matter of changing the design of the ship is relatively simple. If it is desirable to use tubing of a different diameter or wall thickness, no change in apparatus or method is necessary. Tubing can be bought in stock lengths, and it is not necessary to do any threading or fitting.

The ability of oxwelded joints to stand the tremendous stresses of sustained flight with heavy loads and the serious shocks of forced landings has been proved. Although there are, on the average, between 400 and 500 welded joints in a single plane, consultation with a number of the most prominent manufacturers of oxwelded aircraft fails to reveal a single instance of a failure in service of any welded joint. Tests made at the U. S. Army Air Service field at Dayton, Ohio, have indicated that with chrome-molybdenum tubing it is possible to secure an ultimate tensile strength of 96,900 pounds per square inch.

The table on page 429 will be found useful in connection with the welding of sheet steel.

SHEET STEEL WELDING TABLE FOR OXWELD APPARATUS

Thickness of metal		Size of welding head or tip		Oxygen pressure, pounds per square inch	Per hour				Per linear foot, shop practice		
					Speed		Gas consumption		Gas consumption		Steel welding rod, pounds
					Best conditions, linear feet	Shop practice, linear feet	Oxygen, cubic feet	Acetylene	Oxygen, cubic feet	Acetylene, cubic feet	
In.	Gage	W-1	W-9 W-14 W-11								
	32		0	9	36	32	0.8	0.7	0.025	0.022	
	28		1	9	30	26	1.5	1.4	0.058	0.054	
	22	2	2	10	26	22	4.5	4.2	0.20	0.19	
1-32	16	3	3	10	21	17	6.6	6.2	0.39	0.37	0.01
1-16	13	4	4	11	17	14	8.7	8.3	0.62	0.59	0.02
3-32	11	5	5	12	14	11½	10.8	10.2	0.94	0.89	0.04

SECTION X

MATERIALS FOR AIRCRAFT CONSTRUCTION

Materials play such an important part in aircraft construction and a knowledge of both the materials available and their qualities is so important, that it is felt the information that follows will be of service both to builders who have not had the opportunity of wide experience and selecting the right materials for repairs or emergency replacements. The information in this section has been secured from both manufactures of the materials mentioned, large users giving freely of the result of their own experience. The source of the information is given wherever possible.

Materials used in airplane construction or repair require careful consideration both as to kind and quality. Wood has largely given way to metal such as steel, Monel, duralumin and other strong aluminum alloys and similar metals, and in all of them quality is highly important. Standard shapes are naturally used as far as possible and some of the materials available are shown in this section. Tables that give concise information, such as standard dimensions, weight, strength, and other facts of value to those who design or build planes are included, through the kindness of those who desire to aid the industry as a whole by making public the results of their own experience.

Aluminum Alloys.—There are numerous aluminum alloys, some appearing under trade names and each having its own characteristics in most cases. Pure aluminum is but little used but the various alloys known as duralumin, or more commonly as “dural” and by other names are widely used in various grades. While originally a trade name it has come to be applied to many alloys of aluminum in which the strength has been materially increased by the addition of copper and other metals.

Wing ribs have been developed that combine great strength and lightness. A 60-inch Hall rib of Clark design weighs less than a half ounce and yet withstood a load of 850 pounds before failure.

Some who have had a wide experience with aluminum alloys, such as duralumin or its equivalent, contend that not only the strength but the life of this metal depends largely upon the proper heat treatment. They feel that care in avoiding working this metal after it has begun to harden, or age, will greatly increase its life. Disintegration, especially when exposed to salt air or salt water, is said to be one of the results of working this metal without proper heat treatment, or of working it at all after it has begun to age after heating and cooling. Sheets that must be bent or formed should, for example, be worked as soon after heating and quenching as possible, within an hour if it can be done. Rivets used in structures built up of this metal are used within an hour or they go back for reheating. Users cite numerous cases, where rivets that have aged before driving have disintegrated, while those in the same job that were properly treated, have remained sound after several years.

Alclad.—"Alclad" is a comparatively new special combination by which the outside of a piece of metal is coated with pure aluminum although the base is a much stronger alloy of the same material. Alclad sheet consists of a heat-treated strong aluminum alloy base (17 ST) protected from corrosion by smooth, dense surface layers of high purity aluminum, alloyed with the core. The thickness of each surface layer is very uniform; it is $5\frac{1}{2}$ per cent of the total thickness of the sheet. A full cross-section of a piece of 20 gage (0.032 inch) Alclad ST sheet shows the core clearly differentiated from the pure aluminum surface by the etching procedure, which reveals the grain structure of the former without attacking the pure metal.

As the metals look almost identical the makers of Alclad, the Aluminum Company of America, suggest a test that can be easily made in the shop or elsewhere.

Take a piece of aluminum-alloy sheet with a sharp corner and scratch the piece believed to be alclad. The pure aluminum surface of the alclad will show a deeper scratch for the same effort than will a piece of duralumin or other similar alloy. There is also a different feel when the alclad is scratched, so that the difference can be easily detected.

Strong aluminum alloys have been developed to supply strong materials of light weight. The first of these was known as duralumin which is a trade name, although used quite generally to denote the strong alloys of aluminum, copper, and manganese. The specific gravity of these alloys is from 2.69 to 2.82 as compared with 2.71 for

pure aluminum. These strong alloys are primarily wrought materials although heat treatment will greatly improve the cast alloys. The following tables gives the composition, sizes and properties of these alloys as made by the Aluminum Company of America:

	Copper	Manga- nese	Mag- nesium	Silicon	Aluminum minimum
17S.....	4.0	0.5	0.5	....	92.0
B17S.....	3.5	...	0.3	....	94.0
A17S.....	2.5	...	0.3	....	95.0
C17S (Special 17S)...	4.0	0.5	0.5	1.25	92.0
25S.....	4.5	0.8	...	0.8	92.0
51S.....	...	...	0.6	1.0	96.5
195.....	4.5	...	...	....	93.0

These alloys are capable of different heat treatments and have very different characteristics. They are supplied with Hard Wrought Temper H, Soft Temper O, Quenched Temper W, and Heat Treated Temper T. Temper H is only suitable where ductibility is not required, but the metal can be annealed by heating slowly to 650° F. and allowed to cool slowly in the furnace. If dead softness is required it should be heated to 800° F. for about 10 hours, then cooled to 450° F. at a rate not exceeding 25° per hour before removing from the furnace. It is then workable in any way desired. Accurate temperature measurement is necessary for good results.

Pure aluminum is easily welded using either special aluminum wire supplied for the purpose or narrow strips of the sheet metal itself. The strong alloys can also be welded, but with more difficulty. A welding rod containing 5 per cent aluminum silicon is an aid if welding is to be done. It must be remembered, however, that a weld contains cast metal and that the adjacent metal has been softened, so that where strength is important the joint should be riveted.

Various grades of aluminum alloys are selected for different uses. Propellers for example are made of 25ST forgings, while 17ST is recommended for aircraft construction where the sections are thin and highly stressed. As stressed metal is more easily affected by corrosion it

should be protected in use. One method of protection that has been found very satisfactory is to coat the 17ST base with aluminum of high purity which combines the advantages of excellent mechanical properties with exceptional resistance to corrosion. This combination is known as "Alclad." Standard salt-spray tests have practically no effect on this combination. Alclad sheets are supplied in the same tempers as ordinary 17S and in the same gages and sizes.

Heat treatment is easily accomplished in a bath of fused sodium nitrate heated with gas or oil to secure close regulation of temperature. The bath should be stirred to secure even temperature. This can be easily done by raising and lowering the work in the bath, taking care not to raise it above the surface.

The temperature ranges for heat treatment are:

17S-A17S-B17S, 940 to 960° F.

C17S(special 17S), 920 to 940° F.

25S-51S, 960 to 980, preferably 970° F.

While the size of the work affects the time required in the bath, 25 minutes will usually be sufficient. The work should be quenched as soon as possible after removing from the heating bath.

Both hot and cold baths have been used for quenching, but cold water produces a higher resistance to corrosion. Any adhering nitrate must be completely washed from the metal to avoid corrosion due to the tendency of salt to take up moisture. For this reason it is good practice to follow the cold quench with a thorough rinsing in hot water. Unlike steel these alloys do not harden on quenching but grow hard after the treatment. This makes it possible to form or work heat-treated work without damage if the work is done within a short time after quenching. It is considered advisable to perform any bending or forming operations on heat-treated alloys within an hour after quenching; and this is a very strict rule regarding rivets used in this work. It is found advisable to return any rivets not used within the hour to the furnace for reheating.

The following tables are self-explanatory and will be found helpful:

TABLE 1.—MECHANICAL PROPERTIES OF STRONG ALUMINUM ALLOYS

Alloy	Tensile strength, pounds per square inch	Yield point, pounds per square inch	Elongation, per cent in 2 inches	Brinell hardness, 500-kilogram load, 10 mm. ball
51SO	14,000-19,000	4,000-6,000	22-32	25-32
51SW	30,000-40,000	15,000-20,000	20-30	55-70
51ST	45,000-50,000	30,000-40,000	10-18	90-100
25SO	23,000-35,000	7,000-12,000	12-20	45-55
25SW	45,000-53,000	15,000-30,000	15-22	68-85
25ST	55,000-63,000	30,000-40,000	16-25	90-105
17SO	25,000-35,000	7,000-10,000	14-22	45-55
17ST	55,000-63,000	30,000-40,000	18-25	90-105
B17SO	20,000-25,000	.....	20-28	30-40
B17ST	42,000-50,000	20,000-25,000	20-28	65-85
A17SO	20,000-25,000	.....	20-28	30-40
A17ST	35,000-45,000	15,000-20,000	20-28	55-75
C17SO	25,000-35,000	7,000-10,000	12-20	42-55
C17SW	55,000-63,000	30,000-40,000	18-25	90-105
C17ST	63,000-70,000	50,000-55,000	8-14	95-125

TABLE 2.—SPECIFIC GRAVITY

Alloy	25S, 17S and C (Special) 17S	51S	A17S	B17S
Specific gravity.....	2.79	2.69	2.74	2.76
Weight, pounds per cubic inch..	0.101	0.098	0.099	0.100

TABLE 3.—SIZES OF ALUMINUM ALLOY TUBING—X INDICATES COMMERCIAL SIZE

Outside diameter, inches	Wall thickness—inches—stubs gauge																			
	.018	.020	.022	.025	.028	.032	.035	.042	.049	.058	.065	.072	.083	.095	.109	.120	.134	.148	.165	.180
	.203	.220	.238	.259																
3/16																				
1/4																				
5/16																				
3/8																				
7/16																				
1/2																				
9/16																				
5/8																				
3/4																				
13/16																				
7/8																				
1																				
1 1/4																				
1 1/2																				
2																				
2 1/2																				
3																				
3 1/2																				
4																				

NOTE.—In sizes over 1 inch, diameters increase by 1/8 inch increments. For intermediate sizes not listed in the table the minimum wall thickness is the same as the next larger size and the maximum wall thickness the same as the next smaller size. As this table is published, equipment is being installed to increase the maximum diameter to 5 inches. 51S Tubing is manufactured in sizes up to 9 3/8 inches outside diameter. In addition to round tubing, square, rectangular, oval, and other special shapes are manufactured in the strong alloys.

TABLE 4.—MECHANICAL PROPERTIES OF 195 ALLOY

(Data obtained from standard sand-cast unmachined heat-treated test bars)

Alloy	Heat-treatment number	Approximate composition	Tensile strength, pounds per square inch	Elongation per cent in 2 inches	Approximate yield point, pounds per square inch.	Approximate Brinell hardness 10 mm ball -1,000 kg.
195	4	4.5 per cent Cu	28,000-38,000	6-12	13,500	65
195	16	4.5 per cent Cu	30,000-40,000	3-8	21,000	75
195	10	4.5 per cent Cu	36,000-50,000	0-5	27,000	100

ORDINARY ALUMINUM CASTING ALLOYS IN GENERAL USE (FOR COMPARISON)

No. 12	None	8.0 per cent Cu	18,000-23,000	1-3		65
No. 112	None	7.0 per cent Cu	19,000-24,000	1-2.5		65
		2.0 per cent Zn				
		1.2 per cent Fe				
No. 43	None	5.0 per cent Si	17,000-22,000	3-7		40

Special shaped tubing can also be secured in most of the alloy previously mentioned. A new table of stream-lined tubing follows. Square tubing and rectangular tubing with rounded ends can also be found in regular stock.

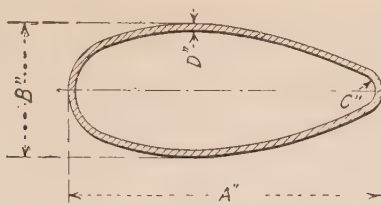


TABLE 5.—STREAM-LINE ALUMINUM ALLOY TUBING

Major axis <i>a</i> , inches	Minor axis <i>b</i> , inches	Wall thick- ness <i>d</i> , inches	Trail- ing edge inside radius <i>c</i> , inches	Weight pounds per foot	Area of wall, square inches	Equiva- lent diameter round, inches	Fine- ness ratio, major to minor	Can be furn- ished in	TMSK No.
6.474	2.760	0.134	0.402	2.330	1.942	4.747	2.345	All	61
5.428	2.300	0.148	0.444	2.180	1.817	4.058	2.360	All	60
5.428	2.300	0.109	0.328	1.605	1.338	4.018	2.360	All	59
4.720	2.000	0.095	0.285	1.270	1.050	3.250	2.360	All	46
4.389	1.860	0.083	0.270	0.982	0.810	3.194	2.360	All	41
4.050	1.716	0.083	0.243	0.933	0.770	3.040	2.360	All	42
4.018	1.760	0.065	0.032	0.778	0.648	3.024	2.285	All	47
4.008	1.760	0.095	0.290	1.070	0.901	3.125	2.318	All	10
3.710	1.572	0.065	0.233	0.674	0.548	2.750	2.360	All	43
3.375	1.430	0.065	0.207	0.601	0.497	2.500	2.360	All	44
3.350	1.500	0.065	0.123	0.634	0.521	2.625	2.234	All	16
3.125	1.188	0.090	0.281	0.790	0.658	2.327	2.633	All	68
3.125	1.188	0.057	0.094	0.456	0.380	2.253	2.633	2S, 3S and 51S	30
3.125	1.188	0.032	0.094	0.271	0.400	2.313	2.633	All	15
3.125	1.188	0.057	0.171	0.456	0.380	2.253	2.633	All	50
3.125	1.188	0.049	0.045	0.436	0.360	2.313	2.633	2S, 3S and 51S	21
3.125	1.188	0.049	0.179	0.407	0.339	2.253	2.633	All	54
3.125	0.375	0.032	0.015	0.247	0.206	2.049	8.340	2S, 3S and 51S	51
*2.750	1.125	0.049	0.201	0.388	0.320	2.130	2.445	All	18
2.700	1.144	0.058	0.160	0.429	0.354	2.000	2.360	All	45
1.875	0.375	0.035	0.012	0.166	0.140	1.310	5.000	All	29
1.625	0.375	0.032	0.063	0.131	0.108	1.106	4.335	All	19
1.219	0.414	0.035	0.047	0.109	0.091	0.844	2.940	2S, 3S and 51S	58

* Elliptical.

Aluminum and Other Light Alloys.—The necessity of saving weight in airplane construction has been responsible for the development of many light alloys that have frequently shown unexpected strength. One of the oldest of these is magnalite which, when die-cast, develops a tensile strength of from 25,000 to 32,400 pounds and a yield point of from 18,000 to 25,000 pounds with a specific gravity of 2.71 or about one-third the weight of cast iron.

Magnalite, as with other alloys, is made in various grades to suit different requirements. It is supplied in castings and ingots and, after heat treatment, runs as high as 40,000 pounds tensile strength, with an elongation of 4 per cent. It is known as Y-metal in some sections and is well known in airplane work.

MAGNESIUM AND ITS ALLOYS¹

Although magnesium was first obtained in 1808, it was only recently that its commercial value for the production of light alloys was recognized. New methods of reducing it from its ores have made possible the production of large quantities of the pure metal at low prices, and it is now being used in automotive production and in places where extreme lightness of parts is required.

Magnesium is the lightest of all known metals. It is only 65 per cent of the weight of aluminum, and only 22 per cent of the weight of steel. Magnesium, when pure, is a lustrous silvery-white metal. Its melting point is 1204° F., which is only 16° below that of aluminum. But when heated in the air to a point slightly above the melting point, magnesium burns with a brilliant white light. The tensile strength of cast magnesium is as low as 13,000 pounds per square inch, and of extruded magnesium 28,000 pounds per square inch. Due to its great affinity for oxygen magnesium is employed as a deoxidizer in melting copper, brass, and nickel. It is also used extensively in fireworks, and for flashlights.

Magnesium is not used commercially in the making of parts except in alloys. The usual alloying metal is aluminum, and the proportions generally vary from 88 to 96 per cent of magnesium and from 4 to 12 per cent of aluminum. Another class of aluminum alloys contains magnesium in only small quantities. Magnesium-aluminum alloys are considerably stronger and tougher than magnesium alone.

Heat Treating.—Sand castings of magnesium alloy containing 88 per cent of magnesium and 12 per cent of aluminum have a tensile strength of only

¹ For the information given we are largely indebted to the American Magnesium Corporation, *American Machinist*, Jan. 13, 1927.

19,000 pounds per square inch, but when heat treated show strengths up to 31,000 pounds per square inch. This alloy, when extruded, has a tensile strength of 45,000 pounds per square inch, and in rolled sheets as high as 53,000 pounds per square inch. Increasing the proportion of magnesium and lowering that of aluminum decreases proportionally the tensile strength of the alloy. A magnesium-aluminum alloy with 96 per cent of magnesium, when cast and heat treated, has a tensile strength of only 25,000 pounds per square inch.

In heat treating magnesium alloy castings it is only necessary to hold them at a temperature of about 800° F. for a short period of time. If the piece is cooled rapidly after treating, a hardening effect takes place.

Magnesium alloys cannot be bent cold easily, but rolled sheet should bend without cracking around a radius three times the thickness of the sheet. Spinning and drawing of magnesium alloys are impractical due to the rapid hardening of the metal under cold work. But hot pressing of the alloys can be done at temperatures from 650 to 850° F. At these temperatures the metal, when compressed into a confined die, will flow into very thin sections and reproduce fine details. Riveting, or upsetting work of any kind, must also be done hot, and with hot tools.

Machining the Alloys.—Magnesium alloys are machined easily. The metal does not tear, and chips do not cling to the tools. A higher speed may be used than is employed for brass. Carbon steel tools are used as for brass, and there is no advantage in using high-speed steel tools. Cutting lubricants are not ordinarily used.

Cutters for milling magnesium alloys should have coarse teeth, and for cutters 3 inches or larger in diameter a clearance angle of 4 degrees is used. For smaller cutters an angle of 6 degrees is employed. Spiral fluted cutters with 15-degree spiral are recommended. Smooth cutting edges on all tools, as for brass, are necessary. The fine cutting edge is obtained with an oil stone. Reaming should also be done with spiral fluted reamers. Carbon steel drills are used on these alloys, and may be run at 150 feet per minute.

For the average turning of magnesium alloys a round nose tool will give good results. It should have a side slope of from 12 to 15 degrees, and a clearance of about 12 degrees. Cutting speeds up to 200 feet per minute can be used for general work. Cuts as deep as $\frac{3}{4}$ inch can be made with a $\frac{1}{32}$ inch feed, but for finishing work fine feeds are recommended.

The fine chips from magnesium alloys will ignite and burn easily, and thus constitute a fire hazard in the shop, but the metal in bulk forms is safe to use without fear of ignition under ordinary circumstances. Magnesium-aluminum alloys are attacked by acids and salt solutions, and also oxidize easily in the air. Parts made of these alloys should therefore be protected by a coat of paint, varnish, or lacquer.

Parts made of magnesium alloys can be brought to a high state of polish by ordinary polishing methods. Sand blasting is also used effectively in cleaning and polishing the parts. In plating magnesium, however, acid solutions must be avoided due to their corrosive action on the metal. For copper plating a cyanide solution is used. Parts to be nickel plated should first be given a coating of copper.

Magnesium alloys have their greatest use where lightness is of first importance. They are being employed for the pistons of automobile engines, and in airplane work for such parts as crankcases, oil pans, gasoline tanks, and small parts.

CHARACTERISTICS OF BRASSES¹

ROLLED SHEET AND STRIP BRASS

Brass is an alloy of copper and zinc in varying proportions. Brasses are more ductile than the corresponding copper-tin alloys or bronzes, but are not as hard. When the zinc content exceeds 45 per cent, however, the alloy becomes very brittle. Brass is malleable and can be readily worked cold. Like most metals, it becomes hard under the cold work, but it can be annealed by simply heating and cooling.

True brass contains only copper and zinc, but tin and lead are sometimes added for special purposes. Iron is an impurity, and ordinarily is considered very detrimental to the alloy. Lead comes as an impurity in the zinc, and a high grade of zinc containing not more than 0.07 per cent is used for the best brass. Tin is sometimes added to give greater strength and hardness, and a desired color. Lead is intentionally added to some mixtures to improve the machining.

The sheet brasses vary in proportion from about 60 per cent copper up to pure copper. They differ in color from light yellow to a copper red. An increase in the copper content produces a golden color, while an increase in the percentage of zinc lightens the color of the alloy to light yellow. The cost of brass increases with the percentage of copper.

More than 75 per cent of all wrought brass contains about 65 per cent copper and 35 per cent zinc, but there are ten general classifications of commercial rolled brass. These brasses are manufactured with different standard degrees of hardness or "temper." This hardness is obtained by cold rolling after the last annealing, and it depends upon the percentage of cold reduction rather than on the passes through the roll. When the thickness is reduced one number of the B. & S. gage, that is, when a No. 18 sheet, 0.040 inch, is reduced to No. 19, 0.036 inch, the resulting sheet is known as $\frac{1}{4}$

¹ For the information given, we are indebted to the Bridgeport Brass Co., *American Machinist*, Oct. 20, 1927.

Hard. When reduced two numbers it is $\frac{1}{2}$ Hard, three numbers $\frac{3}{4}$ Hard, and when reduced four numbers it is Hard. Extra hard is obtained by the reduction of six numbers. Spring Hard by eight numbers, and Extra Spring Hard by ten numbers. However, the softness of the metal before the final rolling has an influence, and if very close limits of temper are desired, the hardness number on some standard testing machine must be specified.

While numbers are applied to the degree of hardness in tempered brass, the grain size is the method of testing the degree of softness of annealed brass. The normal designations of annealed brass are: Deep drawing, drawing, and light annealed; which are sometimes also designated as dead soft, soft, and light annealed. The degree of softness is dependent upon the finished grain size which is produced by a control of the final annealing operations. All grain sizes are measured in millimeters at 75 diameters magnification.

A wide variety of uses can be made of the standard sheet brasses by selecting the one best suited for a given job, and varying its qualities during the fabricating operations. With a given composition, softness in brass is obtained at the expense of strength, and the smoothness of surface when polishing. Likewise, strength and hardness are obtained at the expense of ductility and bending capacity. The following are the ordinary compositions used in sheet and strip brass:

Muntz Metal.—This is the name applying to the group of brasses containing approximately 60 per cent of copper and 40 per cent of zinc. They can be hot rolled as well as cold rolled. Muntz metal sheet is used for ship sheathing and for very large sheets.

Naval Brass.—This brass is sometimes erroneously called Naval Bronze. It contains 60 per cent of copper, $39\frac{1}{4}$ per cent of zinc and $\frac{3}{4}$ per cent of tin. It is used for articles requiring corrosion resistance properties, and can be worked both hot and cold.

Clock Brass.—This brass contains 62 per cent of copper, 36 per cent of zinc, and 2 per cent of lead. It can be cut and blanked with clean sharp edges, and is especially adapted for such parts as clock gears. It will withstand only slight forming and cupping.

High Brass.—This is the most common commercial sheet brass and contains 65 per cent of copper and 35 per cent of zinc. When annealed it is used for general cupping and forming and in the hard tempers it is employed for parts made by blanking, bending, and forming. It is also used for spinning.

Leaded High Brass.—This alloy contains approximately 65 per cent of copper, from $\frac{1}{2}$ to $1\frac{1}{2}$ per cent of lead, and the remainder zinc. It is easier to machine than high brass but is less ductile. It does not foul the threading and putting tools, and is used especially for cut, drawn, and formed

parts on which a clean thread must be cut. This property of free cutting is gained at the expense of its drawing capacity.

Cartridge Brass.—This alloy is made up of 70 per cent of copper and 30 per cent of zinc, the highest grade of zinc being used, containing practically no lead. Its high ductility makes it a good drawing metal, and it derives its name from its use in making deep-drawn cartridge shells.

Low Brass.—An alloy containing 80 per cent of copper and 20 per cent of zinc. It has a fine yellow color, and is used for decorative work.

Rich Low Brass.—An alloy containing 85 per cent of copper and 15 per cent of zinc. The color is reddish, and it is generally used for hardware.

Commercial Bronze.—This alloy derives its name from its bronze color, but it is a true brass. It contains 90 per cent of copper and 10 per cent of zinc. Sometimes it is made up, however, with 88 per cent of copper, 11½ per cent of zinc and ½ per cent of tin.

Gilding Metal.—This alloy contains 95 to 97 per cent of copper and 5 to 3 per cent of zinc. It has a reddish gold color, and is used for the manufacture of jewelry. It is also used in making such articles as bullet jackets and primers.

STEEL TUBING

Steel tubing has become such a factor in the modern airplane that all who have to do with either design, construction, or repair should be familiar with its dimensions, strength, and characteristics. The greatest strength of cold-drawn steel tubing is in its unannealed state. A tube of 1¾ inches outside diameter (hereafter referred to as O.D.) of No. 12 Birmingham Wire Gage or 0.109 inch in thickness, has a tensile strength of 101,500 pounds and a yield point of 65,300 pounds. At this hardness however, the elongation is only 15 per cent with 22 per cent reduction in area. The effect of heating to 930, 1100, and 1300° F. is shown in Table 7. Annealing to these temperatures reduces the tensile strength but increases the ductility or resistance to fracture. These figures also show how steel tubing is affected by temperature such as in welding with either the gas torch or electric arc. Here, however, the heat is largely confined to the weld, where metal is added, and the whole tube is not annealed.

Among the steel tubing used in aircraft construction are what is known as 0.20–0.30 carbon steel and chrome-molybdenum steel. The first contains carbon in the amounts stated and 0.50–0.80 manganese. Its tensile strength is 55,000 and its yield point 36,000 pounds with 22 per cent elongation. The chrome-molybdenum steel has 0.25–0.35

carbon, 0.40–0.60 manganese, 0.80–1.10 chromium, and 0.15–25 molybdenum. It should be obtained normalized to relieve all internal strains. Its tensile strength is 95,000 and the yield point 60,000 with 10 per cent elongation.

For estimating the weight of round seamless steel tubing use the following rule:

Subtract the thickness of the wall from the outside diameter. Multiply the difference by the thickness of the wall in decimals. Multiply this result by the constant 10.68 which gives the weight of tube in pounds per foot. Example: Find the weight of a tube 1 inch in diameter and with $\frac{1}{8}$ inch wall.

1 inch minus $\frac{1}{8}$ or $1.000 - 0.125 = 0.875$. Multiplying by 0.125 = 0.109375. Multiplying this by 10.68 = 1.168 pounds per foot. Tables of the properties of steel tubing are also given.

The tables that follow, 7 to 11 are from the National Tube Company. All weights are figured on the basis of 1 cubic inch of steel weighing 0.2833 pounds and decimals are limited to three places. It is usual to order by outside diameter but this should always be stated, and also whether the outside or inside diameter is most important. Wall thickness is ordered either by Birmingham Wire Gage or by decimals, the latter being preferable in every case.

TABLE 6

Description	Ultimate strength pounds per square inch	Yield point pounds per square inch	Per cent elonga- tion on 2 inches	Reduc- tion of area, per cent
$1\frac{3}{4}$ inches O.D. $\times$ 12 Ga. cold drawn unannealed..... }	101,500	65,300	15	22
$1\frac{3}{4}$ inches O.D. $\times$ 12 Ga. cold drawn 930° F. finish anneal... }	89,700	52,800	25	31
$1\frac{3}{4}$ inches O.D. $\times$ 12 Ga. cold drawn 1100° F. medium anneal }	63,400	46,700	56	42
$1\frac{3}{4}$ inches O.D. $\times$ 12 Ga. cold drawn 1300° F. soft anneal.. }	55,100	37,500	55	48

TABLE 7.—PROPERTIES OF SEAMLESS TUBING
(Sectional area of wall in square inches)

Outside diameter, inches	Thickness in gage and fraction of an inch															
	16 B.W.G. 0.065	15 B.W.G. 0.072	14 B.W.G. 0.083	13 B.W.G. 0.095	12 B.W.G. 0.109	11 B.W.G. 0.120	10 B.W.G. 0.134	9 B.W.G. 0.148	5½ 0.156	8 B.W.G. 0.165	7 B.W.G. 0.180	3¼ 0.187	6 B.W.G. 0.203	7½ 0.218	5 B.W.G. 0.220	4 B.W.G. 0.238
14	0.0377	0.0402	0.0435	0.0462	0.0606	0.0725				0.2384	0.2510	0.2577	0.3089	0.3221	0.3231	0.3360
5½	0.0505	0.0544	0.0598	0.0649	0.0910	0.0961	0.1014		0.2607	0.2708	0.2869	0.2945	0.3488	0.3650	0.3663	0.3828
28	0.0633	0.0685	0.0761	0.0835	0.1124	0.1134	0.1277		0.2914	0.3022	0.3223	0.3313	0.3887	0.4080	0.4095	0.4295
7½	0.0760	0.0826	0.0924	0.1022	0.1338	0.1432	0.1540	0.1636	0.3221	0.3356	0.3576	0.3681	0.3887	0.4309	0.4527	0.4762
1½	0.0888	0.0968	0.1087	0.1208	0.1552	0.1668	0.1803		0.3528	0.3680	0.3930	0.4049	0.4285	0.4509	0.4959	0.5230
9½	0.1015	0.1109	0.1250	0.1395	0.1766	0.1803	0.2066		0.3834	0.4004	0.4283	0.4417	0.4684	0.4939	0.5390	0.5697
58	0.1143	0.1250	0.1413	0.1581	0.1980	0.1903	0.2330		0.3961	0.4141	0.4328	0.4636	0.5082	0.5398	0.5422	0.6164
1½	0.1271	0.1392	0.1576	0.1768	0.2139	0.2195	0.2593		0.4141	0.4328	0.4636	0.5154	0.5481	0.5798	0.5822	0.6632
1½	0.1398	0.1533	0.1739	0.1954	0.2409	0.2610	0.2856		0.4448	0.4652	0.4990	0.5522	0.5879	0.6227	0.6257	0.7099
34	0.1526	0.1674	0.1902	0.2141	0.2495	0.2610	0.2856		0.4755	0.4976	0.5343	0.5890	0.6278	0.6657	0.6686	0.7606
13½	0.1654	0.1816	0.2065	0.2327	0.2623	0.2846	0.3119		0.5062	0.5300	0.5697	0.6258	0.6677	0.7086	0.7115	0.8034
76	0.1781	0.1957	0.2228	0.2514	0.2837	0.3081	0.3362		0.5368	0.5621	0.6040	0.6626	0.7075	0.7516	0.7550	0.8501
15½	0.1909	0.2099	0.2391	0.2700	0.3051	0.3317	0.3645		0.5675	0.5948	0.6404	0.6946	0.7474	0.7946	0.7982	0.8934
1	0.2036	0.2240	0.2554	0.2887	0.3265	0.3553	0.3908		0.5982	0.6280	0.6711	0.7363	0.7872	0.8375	0.8411	0.9435
1½	0.2164	0.2381	0.2717	0.3074	0.3479	0.3788	0.4171		0.6286	0.6596	0.7020	0.7661	0.8271	0.8805	0.8846	0.9830
13½	0.2292	0.2523	0.2880	0.3260	0.3693	0.4024	0.4434		0.6596	0.6920	0.7461	0.8171	0.9068	0.9664	0.9710	1.0370
11½	0.2419	0.2664	0.3045	0.3447	0.3907	0.4260	0.4698		0.6867	0.7209	0.7868	0.8673	0.9665	1.0253	1.0574	1.1305
5½	0.2547	0.2805	0.3205	0.3633	0.4121	0.4495	0.4961		0.7148	0.7505	0.8186	0.8978	0.9865	1.0523	1.0841	1.1639
18	0.2675	0.2947	0.3368	0.3820	0.4335	0.4731	0.5224		0.7448	0.7823	0.8526	0.9305	1.0191	1.0871	1.1382	1.2239
17½	0.2802	0.3088	0.3531	0.4006	0.4519	0.4966	0.5457		0.7755	0.8136	0.8948	0.9741	1.0633	1.1382	1.2302	1.3174
11½	0.2930	0.3230	0.3694	0.4193	0.4763	0.5202	0.5750		0.8062	0.8446	0.9360	1.0126	1.1066	1.1882	1.2941	1.5043
15½	0.3185	0.3512	0.4020	0.4566	0.5191	0.5673	0.6276		0.8366	0.8804	0.9826	1.0606	1.1600	1.2341	1.4030	1.5943
13½	0.3440	0.3795	0.4346	0.4939	0.5619	0.6144	0.6802		0.8672	0.9111	1.0248	1.1048	1.2046	1.3059	1.4894	1.5978
17½	0.3696	0.4078	0.4672	0.5312	0.6047	0.6616	0.7329		0.8977	0.9511	1.0748	1.1548	1.2646	1.3851	1.5178	1.6912
2	0.3951	0.4361	0.4998	0.5685	0.6475	0.7087	0.8007		0.9286	0.9820	1.1166	1.2046	1.3054	1.4818	1.6322	1.8447
2½	0.4461	0.4926	0.5650	0.6431	0.7331	0.8029	0.9434		0.9696	1.0230	1.1676	1.2548	1.3653	1.5077	1.5758	1.7847
24	0.4717	0.5209	0.5976	0.6804	0.7759	0.8501	0.9960		1.0006	1.0540	1.2086	1.2948	1.4184	1.6022	1.6822	1.8782
28	0.4972	0.5492	0.6302	0.7177	0.8187	0.8972	1.0486		1.0306	1.0840	1.2486	1.3399	1.4584	1.6306	1.7486	1.9716
298	0.5227	0.5774	0.6628	0.7550	0.8615	0.9443	1.0486		1.0606	1.1140	1.2886	1.3799	1.4984	1.7395	1.8350	2.0651
294	0.5482	0.6057	0.6954	0.7923	0.9043	0.9914	1.1012		1.0906	1.1440	1.3246	1.4159	1.5344	1.8254	1.9350	2.1716
276	0.5738	0.6340	0.7280	0.8296	0.9471	1.0386	1.1538		1.1206	1.1740	1.4047	1.5046	1.7037	1.9113	2.0413	2.2851
3	0.5993	0.6622	0.7606	0.8670	0.9899	1.0857	1.2065		1.1506	1.2040	1.4995	1.6046	1.8317	2.0413	2.1716	2.4151

TABLE 8.—CONTENTS OF TUBES AND CYLINDERS

Contents in Cubic Feet and United States Gallons of Tubes and Cylinders of Various Inside Diameters and One Foot in Length

(1 gallon = 231 cubic inches = 0.13368 cubic foot. 1 cubic foot = 7.4805 gallons)

Diameter in inches	For 1 foot in length		Diameter in inches	For 1 foot in length		Diameter in inches	For 1 foot in length	
	Cubic feet, also area in square feet	U. S. gallons		Cubic feet, also area in square feet	U. S. gallons		Cubic feet, also area in square feet	U. S. gallons
$\frac{1}{4}$	0.0003	0.0025	$4\frac{3}{4}$	0.1231	0.9206	$11\frac{1}{2}$	0.7213	5.396
$\frac{5}{16}$	0.0005	0.0040	5	0.1364	1.020	$11\frac{3}{4}$	0.7530	5.633
$\frac{3}{8}$	0.0008	0.0057	$5\frac{1}{4}$	0.1503	1.125	12	0.7854	5.875
$\frac{7}{16}$	0.0010	0.0078	$5\frac{1}{2}$	0.1650	1.234	$12\frac{1}{2}$	0.8522	6.375
$\frac{1}{2}$	0.0014	0.0102	$5\frac{3}{4}$	0.1803	1.349	13	0.9218	6.895
$\frac{9}{16}$	0.0017	0.0129	6	0.1963	1.469	$13\frac{1}{2}$	0.9940	7.436
$\frac{5}{8}$	0.0021	0.0159	$6\frac{1}{4}$	0.2131	1.594	14	1.069	7.997
$1\frac{1}{16}$	0.0026	0.0193	$6\frac{1}{2}$	0.2304	1.724	$14\frac{1}{2}$	1.147	8.578
$\frac{3}{4}$	0.0031	0.0230	$6\frac{3}{4}$	0.2485	1.859	15	1.227	9.180
$1\frac{1}{16}$	0.0036	0.0269	7	0.2673	1.999	$15\frac{1}{2}$	1.310	9.801
$\frac{7}{8}$	0.0042	0.0312	$7\frac{1}{4}$	0.2867	2.145	16	1.396	10.44
$1\frac{1}{8}$	0.0048	0.0359	$7\frac{1}{2}$	0.3068	2.295	$16\frac{1}{2}$	1.485	11.11
1	0.0055	0.0408	$7\frac{3}{4}$	0.3276	2.450	17	1.576	11.79
$1\frac{1}{4}$	0.0085	0.0638	8	0.3491	2.611	$17\frac{1}{2}$	1.670	12.49
$1\frac{1}{2}$	0.0123	0.0918	$8\frac{1}{4}$	0.3712	2.777	18	1.767	13.22
$1\frac{3}{4}$	0.0167	0.1249	$8\frac{1}{2}$	0.3941	2.948	$18\frac{1}{2}$	1.867	13.96
2	0.0218	0.1632	$8\frac{3}{4}$	0.4176	3.125	19	1.969	14.73
$2\frac{1}{4}$	0.0276	0.2066	9	0.4418	3.305	$19\frac{1}{2}$	2.074	15.51
$2\frac{1}{2}$	0.0341	0.2550	$9\frac{1}{4}$	0.4667	3.491	20	2.182	16.32
$2\frac{3}{4}$	0.0412	0.3085	$9\frac{1}{2}$	0.4922	3.682			
3	0.0491	0.3672	$9\frac{3}{4}$	0.5185	3.879			
$3\frac{1}{4}$	0.0576	0.4309	10	0.5454	4.080			
$3\frac{1}{2}$	0.0668	0.4998	$10\frac{1}{4}$	0.5730	4.286			
$3\frac{3}{4}$	0.0767	0.5738	$10\frac{1}{2}$	0.6013	4.498			
4	0.0873	0.6528	$10\frac{3}{4}$	0.6303	4.715			
$4\frac{1}{4}$	0.0985	0.7369	11	0.6600	4.937			
$4\frac{1}{2}$	0.1104	0.8263	$11\frac{1}{4}$	0.6903	5.164			

To find the capacity of tubes greater than the largest given in the table, look in the table for a tube of one-half the given size, and multiply its capacity by 4; or one of one-third its size, and multiply its capacity by 9, etc.

To find the weight of water in any of the given sizes, multiply the capacity in cubic feet by $62\frac{1}{4}$ or the capacity in gallons by $8\frac{1}{2}$, or, if a more accurate result is required, by the weight of a cubic foot of water at the actual temperature in the tube.

Given the dimensions of a cylinder in inches, to find its capacity in U. S. gallons: Square the diameter, multiply by the length and by 0.0034. If d = diameter, l = length, gallons

$$= \frac{d^2 \times 0.7854 \times l}{231} = 0.0034dl. \quad \text{If } D \text{ and } L \text{ are in feet, gallons} = 5.875 D^2 L.$$

TABLE 9.—CYLINDRICAL VESSELS
Cylindrical Vessels, Tanks, and Cisterns

Diameter in Feet and Inches, Area in Square Feet and Capacity in U. S. Gals.
for 1 Foot in Depth

(1 gallon = 231 cubic inches = 0.13368 cubic foot. 1 cubic foot = 7.4805 gallons)

Diam- eter, feet inches	Area, square feet	Gallons, 1 foot depth	Diam- eter, feet inches	Area, square feet	Gallons, 1 foot depth	Diam- eter, feet inches	Area, square feet	Gallons, 1 foot depth
1 0	0.785	5.87	4 8	17.10	127.95	13 0	132.73	992.91
1 1	0.922	6.89	4 9	17.72	132.56	13 3	137.89	1,031.5
1 2	1.069	8.00	4 10	18.35	137.25	13 6	143.14	1,070.8
1 3	1.227	9.18	4 11	18.99	142.02	13 9	148.49	1,110.8
1 4	1.396	10.44	5 0	19.63	146.88	14 0	153.94	1,151.5
1 5	1.576	11.79	5 1	20.29	151.82	14 3	159.48	1,193.0
1 6	1.767	13.22	5 2	20.97	156.83	14 6	165.13	1,235.3
1 7	1.969	14.73	5 3	21.65	161.93	14 9	170.87	1,278.2
1 8	2.182	16.32	5 4	22.34	167.12	15 0	176.71	1,321.9
1 9	2.405	17.99	5 5	23.04	172.38	15 3	182.65	1,366.4
1 10	2.640	19.75	5 6	23.76	177.72	15 6	188.69	1,411.5
1 11	2.885	21.58	5 7	24.48	183.15	15 9	194.83	1,457.4
2 0	3.142	23.50	5 8	25.22	188.66	16 0	201.06	1,504.1
2 1	3.409	25.50	5 9	25.97	194.25	16 3	207.39	1,551.4
2 2	3.687	27.58	5 10	26.73	199.92	16 6	213.82	1,599.5
2 3	3.976	29.74	5 11	27.49	205.67	16 9	220.35	1,648.4
2 4	4.276	31.99	6 0	28.27	211.51	17 0	226.98	1,697.9
2 5	4.587	34.31	6 3	30.68	229.50	17 3	233.71	1,748.2
2 6	4.909	36.72	6 6	33.18	248.23	17 6	240.53	1,799.3
2 7	5.241	39.21	6 9	35.78	267.69	17 9	247.45	1,851.1
2 8	5.585	41.78	7 0	38.48	287.88	18 0	254.47	1,903.6
2 9	5.940	44.43	7 3	41.28	308.81	18 3	261.59	1,956.8
2 10	6.305	47.16	7 6	44.18	330.48	18 6	268.80	2,010.8
2 11	6.681	49.98	7 9	47.17	352.88	18 9	276.12	2,065.5
3 0	7.069	52.88	8 0	50.27	376.01	19 0	283.53	2,120.9
3 1	7.467	55.86	8 3	53.46	399.88	19 3	291.04	2,177.1
3 2	7.876	58.92	8 6	56.75	424.48	19 6	298.65	2,234.0
3 3	8.296	62.06	8 9	60.13	449.82	19 9	306.35	2,291.7
3 4	8.727	65.28	9 0	63.62	475.89	20 0	314.16	2,350.1
3 5	9.168	68.58	9 3	67.20	502.70			
3 6	9.621	71.97	9 6	70.88	530.24			
3 7	10.085	75.44	9 9	74.66	558.51			
3 8	10.559	78.99	10 0	78.54	587.52			
3 9	11.045	82.62	10 3	82.52	617.26			
3 10	11.541	86.33	10 6	86.59	647.74			
3 11	12.048	90.13	10 9	90.76	678.95			
4 0	12.566	94.00	11 0	95.03	710.90			
4 1	13.095	97.96	11 3	99.40	743.58			
4 2	13.635	102.00	11 6	103.87	776.99			
4 3	14.186	106.12	11 9	108.43	811.14			
4 4	14.748	110.32	12 0	113.10	846.03			
4 5	15.321	114.61	12 3	117.86	881.65			
4 6	15.90	118.97	12 6	122.72	918.00			
4 7	16.50	123.42	12 9	127.68	955.09			

TABLE 10.—"SHELBY" COLD-DRAWN SEAMLESS STEEL TUBING—ROUND
(Weight in Pounds per Foot)

Thickness B. W. G. & Fractions	Equivalent in Decimal of Inch	OUTSIDE DIAMETER IN INCHES													
		$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$2\frac{1}{16}$	$2\frac{1}{8}$
20	0.035	0.17	0.22	0.27	0.31	0.36	0.41	0.45							
18	0.049	0.24	0.30	0.37	0.43	0.50	0.56	0.63							
16	0.065	0.30	0.39	0.47	0.55	0.74	0.82	0.91	1.00	1.08					
14	0.083	0.37	0.48	0.59	0.70	0.81	0.92	1.03	1.14	1.25	1.37	1.48	1.59	1.70	
13	0.090	0.41	0.54	0.66	0.79	0.92	1.04	1.17	1.30	1.42	1.55	1.68	1.80	1.93	
12	0.109	0.45	0.60	0.75	0.89	1.04	1.18	1.33	1.47	1.62	1.76	1.91	2.06	2.20	2.35
11	0.120	0.49	0.65	0.81	0.97	1.13	1.29	1.45	1.61	1.77	1.93	2.09	2.25	2.41	2.57
10	0.134	0.52	0.70	0.88	1.06	1.24	1.42	1.60	1.77	1.95	2.13	2.31	2.49	2.67	2.85
	0.156	0.99	1.20	1.41	1.61	1.82	2.03	2.24	2.45	2.66	2.87	3.07	3.28	3.49	3.70
	0.188	1.13	1.38	1.63	1.88	2.13	2.38	2.63	2.88	3.13	3.38	3.63	3.88	4.13	4.38
	0.219		1.53	1.82	2.12	2.41	2.70	2.99	3.28	3.57	3.87	4.16	4.48	4.74	5.03
	0.250				2.00	2.33	2.67	3.00	3.33	3.67	4.00	4.33	4.67	5.00	5.33
	0.281						2.91	3.28	3.66	4.03	4.41	4.78	5.16	5.53	5.91
	0.313						3.13	3.54	3.96	4.38	4.79	5.21	5.63	6.04	6.46
	0.375						3.50	4.00	4.50	5.00	5.50	6.00	6.50	7.50	8.00
	0.438							4.38	4.96	5.54	6.13	6.71	7.29	7.88	8.46
	0.500								5.33	6.00	6.67	7.33	8.00	8.67	9.34
	0.562										7.13	7.88	8.63	9.38	10.13
	0.625												9.17	10.00	10.84
	0.750													14.00	15.00
	0.875														
1	1.000														

Hot rolled from 2-inch diameter No. 11 gage to 9 inches and 1 inch thick. Same weights as above.

To assist in calculating the strength of steel tubing of standard dimensions, Table 7 giving the sectional area of the metal in tubes of diameters from $\frac{1}{4}$ to 3 inches and in thicknesses from No. 16 to $\frac{3}{32}$ inch are given, these sizes covering practically all airplane requirements.

It sometimes happens that tubes are used as containers and in such cases Table 8 will be found useful, while Table 9 gives the capacity of cylindrical tanks from 1 to 20 feet in diameter. Available tube lengths are given in Table 11.

STANDARD GAGES FOR WIRE AND PLATE

A knowledge of just what is meant by different wire gages is always convenient when either constructing or repairing airplanes. But in spite of the tables given below, for convenience, all makers of steel and similar products strongly advise that sizes be specified in thousandths of an inch. If not, the name of the gage used should always be given. To avoid misunderstandings the following list should be consulted before ordering, as various materials are designated by different gages.

The mills use:

Birmingham or Stubs gage for bands, hoops, spring steel, steel tubing, and strip steel.

Washburn & Moen gage for steel wire except music wire, which takes the music wire gage. Armature binding wire is made to Brown & Sharpe gage.

Brown & Sharpe gage for brass sheets, brass strips, copper sheets, nickel-silver sheets and wire, phosphor-bronze strip, armature-binding wire.

U. S. Standard gage for steel sheets, pure nickel sheets, and Monel.

Music-wire gage for bricketting wire, choker and control wire, music spring wire, piano wire, and spinning wire.

TABLE 12.—DIMENSIONS IN DECIMAL PARTS OF AN INCH

Number of Gage	American or Brown & Sharpe	Birmingham or Stubs' Iron Wire	Washburn & Moen Mfg. Co.	Trenton Iron Co.	Stubs' Steel Wire	Imperial Wire Gage	U. S. Standard for Plate
000000	.....	.....	.....	.....	.....	.464	.46875
00000	.....	.....	.....	.450	.....	.432	.4375
0000	.46	.454	.3938	.400	.....	.400	.40625
000	.40964	.425	.3625	.360	.....	.372	.375
00	.3648	.380	.3310	.330	.....	.348	.34375
0	.32486	.340	.3065	.305	.....	.324	.3125
1	.2893	.300	.2830	.285	.227	.300	.28125
2	.25763	.284	.2625	.265	.219	.276	.265625
3	.22942	.259	.2437	.245	.212	.252	.25
4	.20431	.238	.2253	.225	.207	.232	.234375
5	.18194	.220	.2070	.205	.204	.212	.21875
6	.16202	.203	.1920	.190	.201	.192	.203125
7	.14428	.180	.1770	.175	.199	.176	.1875
8	.12849	.165	.1620	.160	.197	.160	.171875
9	.11443	.148	.1483	.145	.194	.144	.15625
10	.10189	.134	.1350	.130	.191	.128	.140625
11	.090742	.120	.1205	.1175	.188	.116	.125
12	.080808	.109	.1055	.105	.185	.104	.109375
13	.071961	.095	.0915	.0925	.182	.092	.09375
14	.064084	.083	.0800	.080	.180	.080	.078125
15	.057068	.072	.0720	.070	.178	.072	.0703125
16	.05082	.065	.0625	.061	.175	.064	.0625
17	.045257	.058	.0540	.0525	.172	.056	.05625
18	.040303	.049	.0475	.045	.168	.048	.05
19	.03589	.042	.0410	.040	.164	.040	.04375
20	.031961	.035	.0348	.035	.161	.036	.0375
21	.028462	.032	.03175	.031	.157	.032	.034375
22	.025347	.028	.0286	.028	.155	.028	.03125
23	.022571	.025	.0258	.025	.153	.024	.028125
24	.0201	.022	.0230	.0225	.151	.022	.025
25	.0179	.020	.0204	.020	.148	.020	.021875
26	.01594	.018	.0181	.018	.146	.018	.01875
27	.014195	.016	.0173	.017	.143	.0164	.0171875
28	.012641	.014	.0162	.016	.139	.0149	.015625
29	.011257	.013	.0150	.015	.134	.0136	.0140625
30	.010025	.012	.0140	.014	.127	.0124	.0125
31	.008928	.010	.0132	.013	.120	.0116	.0109375
32	.00795	.009	.0128	.012	.115	.0108	.01015625
33	.00708	.008	.0118	.011	.112	.0100	.009375
34	.006304	.007	.0104	.010	.110	.0092	.00859375
35	.005614	.005	.0095	.0095	.108	.0084	.0078125
36	.005	.004	.0090	.009	.106	.0076	.00703125
37	.004453			.0085	.103	.0068	.006640625
38	.003965			.008	.101	.0060	.00625
39	.003531			.0075	.099	.0052	
40	.003144			.007	.097	.0048	

AIRPLANE STEEL WIRE AND CABLE

The distinction between wire and cable is that "wire" is a single wire while a cable is made up of several individual wires in various combinations. Airplane cables are frequently referred to as airplane "strand" and are designated by numbers that tell how the cable is made up. Where but one number is given, as a 19 strand, 19 wires are arranged into a single strand as shown above Table 13, where a central wire is surrounded by two layers of 6 and 12 wires. Such a strand is not very flexible and is used principally for stays. The sizes most commonly used are $\frac{1}{8}$ and $\frac{3}{32}$ inch. The makers state that about

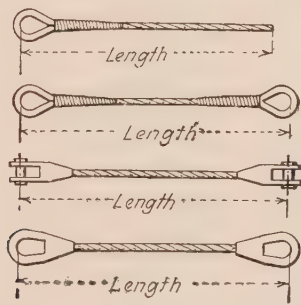


FIG. 1.—How to give dimensions on cables with fittings.

600 feet are required for staying a biplane and 250 for a monoplane of average size. Smaller sizes are used for light stays. The $\frac{1}{32}$ inch size has but 7 wires.

When two numbers are given as in Table 14, the first shows the number of strands, the second the number of wires in each strand. The 6 by 7 cord shown has a cotton center and 6 strands of 7 wires each around it. Such a cord is flexible enough to use for the controls such as steering gear and ailerons. Substituting a steel strand in the center for the cotton adds about 10 per cent to the strength but reduces the flexibility. The tables give the weight and strength of the various sizes. In ordering cables made up with fittings it is customary to measure to the "pull" of the fitting. The four small diagrams (Fig. 1) show where the measurements are to be taken, with several different arrangements

of fittings. All steel wires, cords, or cables are either galvanized or tinned to prevent corrosion.

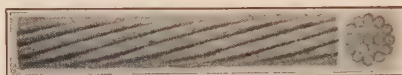


TABLE 13.—ROEBLING 19-WIRE GALVANIZED AIRCRAFT STRAND

Diameter of strand, inches	Breaking strength of strand, pounds	Approximate weight, pounds per 100 feet
$\frac{1}{2}$	28,500	53.9
$\frac{7}{16}$	23,500	40.6
$\frac{3}{8}$	17,500	30.1
$\frac{5}{16}$	12,500	20.65
$\frac{9}{32}$	10,000	17.67
$\frac{1}{4}$	8,000	13.50
$\frac{7}{32}$	6,100	10.00
$\frac{3}{16}$	4,600	7.70
$\frac{5}{32}$	3,200	5.50
$\frac{1}{8}$	2,100	3.50
$\frac{7}{64}$	1,600	2.60
$\frac{3}{32}$	1,100	1.75
$\frac{5}{64}$	780	1.21
$\frac{1}{16}$	500	.78
$\frac{1}{32}$ 7-wire	185	.30



TABLE 14.—ROEBLING 6×7 GALVANIZED AIRCRAFT CORD

Diameter of cord, inches	Breaking strength of cord, pounds	Approximate weight, pounds per 100 feet
$\frac{1}{2}$	20,000	37.80
$\frac{7}{16}$	14,200	28.60
$\frac{3}{8}$	11,800	20.70
$\frac{5}{16}$	7,900	15.00
$\frac{9}{32}$	6,200	12.40
$\frac{1}{4}$	5,000	9.50
$\frac{7}{32}$	4,000	7.43
$\frac{3}{16}$	2,750	5.30
$\frac{5}{32}$	2,200	4.20
$\frac{1}{8}$	1,150	2.20
$\frac{7}{64}$	830	1.50
$\frac{3}{32}$	780	1.30
$\frac{5}{64}$	480	0.83
$\frac{1}{16}$	400	0.73

Standard airplane fittings adopted by the S. A. E. are given in Sec. XI.

STANDARD TINNED AIRCRAFT WIRE

This wire represents one of the highest developments in the art of wire drawing. It must have as high a tensile strength as possible in order that the weight may be reduced to a minimum. It must be very uniform and tough, and sufficiently pliable to be bent into an eye for the ferrule terminal connection without danger of fracture.

These requirements are met by using the highest grade of steel suitable for the purpose; by employing special care in drawing the wire, and by conducting exacting tests and inspections throughout the entire manufacture.

Table 15 gives the specifications for Roebling Standard Tinned Aircraft Wire.

TABLE 15.—STANDARD TINNED AIRCRAFT WIRE

Steel-wire gage	Diameter, inches	Weight per 100 feet, pounds	Torsion test, number of turns in eight inches (minimum)	Bend test, number of bends (minimum)	Breaking strength, pounds (minimum)	Tensile strength, pounds per square inch (minimum)
0	0.306	24.87	3	2	14,000	190,000
1	0.283	21.14	4	2	12,100	192,000
2	0.262	18.25	5	2	10,520	195,000
3	0.244	15.71	5	2	9,200	197,000
4	0.225	13.36	6	3	7,950	200,000
5	0.207	11.31	8	3	6,850	204,000
6	0.192	9.73	9	4	6,030	208,000
7	0.177	8.27	9	4	5,250	213,000
8	0.162	6.93	11	5	4,520	219,000
9	0.148	5.78	12	6	3,850	224,000
10	0.135	4.81	15	7	3,290	230,000
11	0.120	3.80	17	9	2,670	236,000
12	0.105	2.91	21	11	2,090	241,000
13	0.091	2.23	25	14	1,600	248,000
14	0.080	1.69	29	17	1,260	252,000
15	0.073	1.37	33	21	1,040	255,000
16	0.062	1.05	38	25	775	258,000
17	0.054	0.770	46	31	600	263,000
18	0.047	0.583	53	39	460	268,000
19	0.041	0.444	63	50	356	270,000
20	0.034	0.323	74	78	250	275,000
21	0.032	0.270	84	85	225	280,000

DESIGN VALUES OF VARIOUS MATERIALS FOR AIRPLANE DESIGN

The following tables, 16 to 23, are given by the courtesy of the Glenn L. Martin Co. as compiled and calculated by their chief engineer, L. C. Milburn.

These include steel sheets, steel tubing, steel bars, bars and tubing sheets of various non-ferrous metals, castings and wood of various kinds.

These tables are largely self-explanatory. The values given in the columns, such as tensile strength, are in 1,000 pounds, elongation being in percentage. The heat treatments referred to are those recommended by the S. A. E. and are given by number. The table regarding woods used is very comprehensive and gives about all the information that can be desired.

TABLE 16.—DESIGN VALUES FOR STEEL SHEET

Thickness 0.020 to 0.180 inch¹

(Values in 1,000 pounds)

Specifi- cation (SAE)	Condition	Tensile strength	Yield point, tension	Shear strength	Bearing strength (2)	Elonga- tion in 2 inches, per cent
1,010 Steel	Annealed	47	28	30	65	30
	As rolled	50	32	35	75	25
1,025 Steel	Annealed	50	35	34	55	25
	As rolled	55	36	35	60	20
1,095 Steel	Annealed	75	50	51	100	17
	As rolled	100	90	75	150	10
2,330 Steel	Annealed	80	55	50	90	20
	As rolled	100	70	80	115	15
	Heat treated	125	110	100	125	16
	Heat treated	150	135	125	150	13
24,130 Steel	Annealed	70	55	50	100	18
	As rolled					
	Heat treated	125	100	100	125	16
	Heat treated	150	125	125	150	11
6,140 Steel	Annealed	95	65	70	120	18
	As rolled	125	80	90	140	15

¹ For sheet of thickness greater than 0.180 inch use values given for bar stock received in annealed condition unless otherwise specified.

² For pin joints subject to reversible stress, design for 150 per cent of calculated load.

TABLE 17.—DESIGN VALUES FOR STEEL TUBING

O.D. = 0.5 to 2.5 inches, wall thickness = 0.025 to 0.180 inch

(Values in 1,000 pounds)

Speci- fication	Condition	Tensile strength	Yield point in ten- sion	Shear strength	Bearing strength (1)	Tor- sional strength (2)	Elong- ation in 2 inches in per cent
1,010 Steel	Annealed As drawn						
1,025 Steel	Annealed As drawn	50 65	35 40	34 45	55 70	.....	25 20
2,330 Steel	Annealed	85	60	62	95	.....	20
	As drawn	100	70	85	110	.....	15
	Heat treated	125	110	100	125	.....	15
	Heat treated	150	135	125	150	.....	12
4,130 Steel	Annealed	70	55	50	100	.....	18
	As drawn	95	60	60	125	.....	15
	Heat treated	125	100	100	125	.....	15
	Heat treated	150	125	125	150	.....	10
6,140 Steel	Annealed As drawn						

¹ For pin joints subject to reversible stress, design for 150 per cent of calculated load.² Calculate torsional values from diameter-thickness ratio.

TABLE 18.—DESIGN VALUES FOR STEEL BAR
Average for 1 inch diameter round stock
(Values in 1,000 pounds)

Speci- fication	Condition	Tensile strength	Yield point ten- sion	Shear strength (1)	Bearing strength (1)	Tor- sional strength	Elon- gation in 2 inches
1,010 Steel	Annealed	48	30	35	50	38	25
	As rolled	52	35	38	55	40	22
1,025 Steel	Annealed	50	35	35	55	38	25
	As rolled	55	36	38	60	40	20
1,040 Steel	Annealed	80	50	60	90	64	20
	As rolled	90	55	67	100	72	15
	Heat treated						
2,330 Steel	Annealed	85	60	64	95	68	20
	As rolled	100	68	75	110	80	18
	Heat treated	125	110	100	125	100	16
	Heat treated	150	135	125	150	125	13
2,340 Steel	Annealed	90	65	67	100	72	20
	As rolled	120	78	90	125	95	17
	Heat treated	125	110	100	125	100	15
	Heat treated	150	135	125	150	125	12
4,130 Steel	Annealed	65	44	50	80	45	22
	As rolled	80	56	60	95	55	16
	Heat treated	125	100	100	125	100	15
	Heat treated	150	125	125	150	125	10
6,130	Annealed	90	60	67	100	65	20
	As rolled	110	75	82	120	80	17
	Heat treated						
	Heat treated						

¹ For pin joints subject to reversible stress, design for 150 per cent of calculated load.

TABLE 19.—DESIGN VALUES FOR NON-FERROUS SHEET
 Thickness 0.020 to 0.120 inches
 (Values in 1,000 pounds)

Specifica- tion	Condition	Tensile strength	Yield point, ten- sion	Shear strength	Bearing strength (1)	Elong- ation in 2 inches, per cent
Compressed brass.....	Soft	35	....	..	..	40
Spec. 47B2e...	As rolled	40	....	21	..	20
Naval brass...						
Spec. 46B6f...	As rolled	55	27	33	..	35
Phosphor.....	Medium	50	25	..	..	25
Bronze.....	Tempered	85				
Copper.....	Annealed	30	....	..	..	25
Spec. 47C2c...	As rolled	35	....	20	..	18
Aluminum....	One-half hard	16	....	10	..	7
Spec. 37-A....	Hard	22	....	..	..	2
17 SO.....	Annealed	30	18	17	45	18
17 ST.....	Tempered	55	30	27	60	
Alclad.....	Annealed	24	18.5	..	..	15
	Tempered	50	30	27	60	18
Monel metal...	As rolled	60	25	..	..	25

For sheet of thickness greater than 0.180 inches, use values given for bar stock.

For pin joints subject to reversible stress, design for 150 per cent of calculated load

TABLE 20.—DESIGN VALUES FOR NON-FERROUS TUBING
 O.D. = 0.5 to 2.5 inches, wall thickness 0.025 to 0.180 inches
 (Values in 1,000 pounds)

Specification	Condition	Tensile strength	Yield point, tension	Shear strength	Bearing strength (1)	Torsional strength (2)	Elongation in 2 inches per cent
Commercial brass Spec. 44T15.....	Annealed	35	..	24	..	..	30
	As drawn	40	..	30	..	..	20
Naval brass..... Spec. 46B6f.....	Annealed						
	As drawn	55	22	..	..	..	32
Phosphor..... Bronze.....							
Copper..... Spec. 35-B.....	Annealed	30	..	..	..	..	30
	As drawn	35	..	..	..	..	25
Aluminum..... Spec. 44A1.....	Half hard	16	..	..	..	..	20
	Hard	22	..	..	..	..	5
17 SO.....	Annealed	30	20	18	45	..	20
17 ST.....	Tempered	55	30	27	65	..	6

¹ For pin joints subject to reversible stress, design for 150 per cent of calculated load.

² Calculate torsional values from diameter-thickness ratio.

TABLE 21.—DESIGN VALUES FOR NON-FERROUS BAR AND EXTRUDED SECTIONS
(Values in 1,000 pounds)

Specification	Condition	Tensile strength	Yield point in tension	Shear strength	Bearing strength (1)	Tor-sional strength	Elonga-tion in 2 inches
Commercial brass.....	Annealed As rolled	50	..	..	..	..	15
Naval brass...	Annealed As rolled	60	..	..	..	..	20
Phosphor bronze.....	As rolled	65	45	..	..	..	18
Aluminum....	Half hard Hard	20	..	..	35	..	5
17 SO Bar....	Annealed	50	25	30	65	..	10
17 ST Bar....	Tempered						
17 SO Ext....	Annealed	50	25	30	65	..	16
17 ST Ext....	Tempered						

¹ For pin joints subject to reversible stress, design for 150 per cent of calculated load.

TABLE 22.—DESIGN VALUES FOR CASTINGS
(Values in 1,000 pounds)

Specification	Tensile strength	Yield point, tension	Shear strength	Bearing strength ¹	Elongation in 2 inches, per cent	Rockwell hard- ness	Modulus of elas- ticity	Pouring tempera- ture, degrees Fahrenheit	Shrinkage, inches/feet
Aluminum spec. 30	18	..	..	30	1.5	..	..	1,300	0.125
195 heat treated...	25	..	..	40	5	..	..	1,300	0.156
Yellow brass.....	25	..	..	38	18	..	..	1,700	0.210
Gunmetal spec. 46M6d.....	40	..	..	..	20				
Manganese bronze spec. 49B3b.....	65	..	..	..	20				
Cast iron spec. 4912a.....	20	..	..	80	.....	..	..	2,500	0.125
Malleable iron spec. 4618.....	50	..	..	..	10	..	..	.....	0.250
Manganese steel cast.	For excessive wear; cannot be machined.							2,400	

¹ For pin joints subject to reversible stress, design for 150 per cent of calculated load.

TABLE 23.—DESIGN VALUES OF WOODS—THESE DATA ALLOW FOR 15 PER CENT MOISTURE

Hardwoods:	Specific gravity based on volume and weight when oven dry		Shrinkage from green to oven dry condition		Static bending				Compression parallel to grain		Shearing strength parallel to grain, pounds per square inch	Hardness, side load required to imbed 0.444 inch ball to one-half its diameter, pounds		
	Average	Minimum permitted	Weight at 15 per cent moisture, pounds per cubic foot	Radial percentage		Tangential percentage	Fiber stress at elasticity limit, pounds per square inch	Modulus of rupture, pounds per square inch	Modulus of elasticity, 1,000 pounds per square inch	Work to maximum load, inch pounds per cubic inch			Fiber stress at elastic limit, pounds per square inch	Maximum crushing strength, pounds per square inch
1. Ash, black.....	0.53	0.48	0.35	6,400	11,900	1,340	14.3	4,050	5,400	1,080	1,050	760		
2. Ash, commercial white.....	0.62	0.56	0.41	8,900	14,800	1,460	14.2	5,250	7,000	1,920	1,380	1,180		
3. Basswood.....	0.40	0.36	0.26	5,600	8,600	1,250	6.6	3,370	4,500	530	720	370		
4. Beech.....	0.66	0.60	0.44	8,200	14,200	1,440	13.5	4,880	6,500	1,430	1,300	1,060		
5. Birch.....	0.68	0.58	0.44	7.0	15,500	1,780	18.2	5,480	7,300	1,300	1,300	1,100		
6. Cherry, black.....	0.53	0.48	0.36	8,500	12,500	1,330	11.7	5,100	6,800	1,000	1,180	900		
7. Cottonwood.....	0.43	0.39	0.29	5,600	8,600	1,190	7.4	3,520	4,700	560	660	410		
8. Elm, cork.....	0.66	0.60	0.45	7,900	13,000	1,340	19.3	5,180	6,900	1,790	1,360	1,230		
9. Gum, red.....	0.53	0.48	0.34	7,500	11,600	1,290	10.9	4,050	5,400	1,010	1,100	650		
10. Hickory, true.....	0.79	0.71	0.51	10,600	19,300	1,860	27.5	6,520	8,700	2,650	1,440	720		
11. Mahogany, African.....	0.47	0.42	0.32	7,900	10,800	1,280	8.0	4,280	5,700	1,200	980	790		
12. Mahogany, true.....	0.51	0.46	0.34	8,800	11,600	1,260	7.3	4,880	6,500	1,510	860	790		
13. Maple, sugar.....	0.67	0.60	0.44	9,500	13,000	1,600	13.7	5,620	7,500	1,850	1,520	1,270		
14. Oak, com. white.....	0.69	0.62	0.45	7,800	13,800	1,490	13.6	4,950	6,600	1,600	1,300	1,240		
15. Poplar, yellow.....	0.43	0.38	0.28	6,000	9,100	1,300	6.5	3,750	5,000	690	800	420		
16. Walnut, black.....	0.56	0.52	0.39	10,200	15,100	1,490	11.4	5,700	7,600	1,480	1,000	990		
Conifers:														
17. Cedar, incense.....	0.36	0.32	0.25	6,000	8,700	1,020	5.6	4,320	5,400	770	650	450		
18. Cedar, Pt. Orford.....	0.44	0.40	0.30	7,400	11,000	1,520	8.7	4,880	6,100	880	760	520		
19. Cedar, western red.....	0.34	0.31	0.23	5.1	7,800	1,030	5.8	4,000	5,000	680	630	320		
20. Cedar, white (northern).....	0.32	0.29	0.22	4.9	6,600	700	4.9	3,040	3,800	480	610	300		
21. Cypress, bald.....	0.48	0.43	0.32	7,100	10,500	1,270	7.7	4,960	6,200	1,050	720	480		
22. Douglas fir.....	0.51	0.45	0.34	8,000	11,500	1,700	8.1	5,600	7,400	1,100	810	620		
23. Pine, Norway.....	0.51	0.46	0.34	7.2	11,900	1,560	8.9	5,280	6,600	920	870	520		
24. Pine, sugar.....	0.38	0.34	0.26	5,600	8,000	1,040	5.4	3,680	4,600	690	730	370		
25. Pine, western white.....	0.42	0.38	0.27	4.1	9,300	1,310	7.9	4,240	5,300	640	640	360		
26. Pine, white.....	0.38	0.34	0.26	6.0	8,700	1,140	6.3	3,840	4,800	670	640	380		
27. Spruce.....	0.40	0.36	0.27	6,200	9,400	1,300	7.8	4,000	5,000	750	720	440		

OTHER SPECIAL SHAPES

The structural shapes shown herewith (Figs. 2 to 7) have been developed by Paul G. Zimmerman and B. V. Korvin-Kroukovsky especially

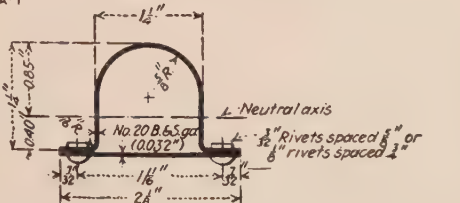
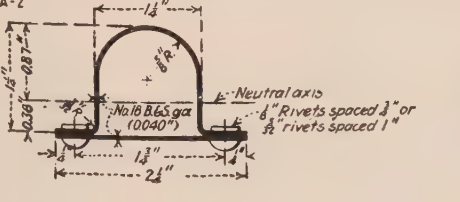
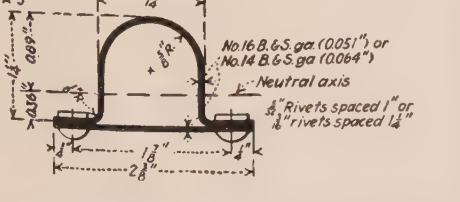
Shape and Dimensions	Properties
A-1  1 1/2" (top flange width) 1 1/4" (total height) 0.85" (web height) 1/16" (web thickness) 1/8" (bottom flange thickness) 2 3/8" (total width) No. 20 B.S. ga. (0.032") 3/32" Rivets spaced 5/8" or 1" Neutral axis	$A = 0.20 \text{ sq. in.}$ $I = 0.046 \text{ in.}^4$ $Z = 0.054 \text{ in.}^3$ $K = 0.48 \text{ in.}$ $W_1 = 20 \text{ lb.}$ $W_2 = 22 \text{ lb.}$
A-2  1 1/2" (top flange width) 1 1/4" (total height) 0.87" (web height) 1/16" (web thickness) 1/8" (bottom flange thickness) 2 3/8" (total width) No. 16 B.S. ga. (0.040") 3/32" Rivets spaced 5/8" or 1" Neutral axis	$A = 0.25 \text{ sq. in.}$ $I = 0.057 \text{ in.}^4$ $Z = 0.066 \text{ in.}^3$ $K = 0.46 \text{ in.}$ $W_1 = 0.26$ $W_2 = 0.28$
A-3  1 1/2" (top flange width) 1 1/4" (total height) 0.89" (web height) 1/16" (web thickness) 1/8" (bottom flange thickness) 2 3/8" (total width) No. 16 B.S. ga. (0.051") or No. 14 B.S. ga. (0.064") 3/32" Rivets spaced 1" or 1 1/4" Neutral axis	$A = 0.330 \text{ sq. in.}$ $I = 0.083 \text{ in.}^4$ $Z = 0.083 \text{ in.}^3$ $K = 0.47 \text{ in.}$ $W_1 = 0.32$ $W_2 = 0.34$ $A = 0.41 \text{ sq. in.}$ $I = 0.092 \text{ in.}^4$ $Z = 0.104 \text{ in.}^3$ $K = 0.47 \text{ in.}$ $W_1 = 0.37$ $W_2 = 0.40$
A = Area I = Moment of inertia Z = Section modulus K = Radius of gyration	W_1 = Weight without watertight packing strips, in lb. per foot run. W_2 = Weight with watertight packing strips, in lb. per foot run.

FIG. 2.—Dimensions of shallow channels. Aeromarine standards. Properties of structural shapes.

for use in airplanes and flying boats. The material, a product of the Aluminum Company of America, is what is known as 17S alloy, an aluminum-copper alloy which may be compared with duralumin.

The sheets vary in thickness as shown and the rivets used are also given. Table 24 for shear and bearing values of duralumin or similar rivets has been revised to agree with those recommended by the Depart-

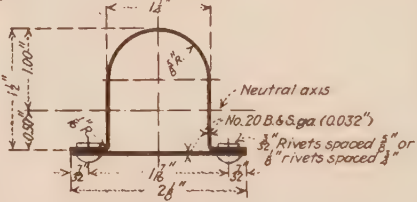
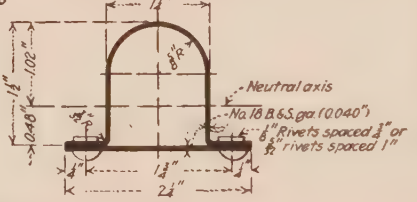
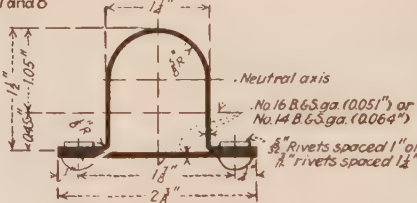
Shape and Dimensions		Properties
A-5 		$A = 21 \text{ sq. in.}$ $I = .0072 \text{ in.}^4$ $Z = .0072 \text{ in.}^3$ $K = .58 \text{ in.}$ $W_1 = .022$ $W_2 = .024$
A-6 		$A = .027 \text{ sq. in.}$ $I = .0088 \text{ in.}^4$ $Z = .0086 \text{ in.}^3$ $K = .57 \text{ in.}$ $W_1 = .029$ $W_2 = .031$
A-7 and 8 		$A = .036 \text{ sq. in.}$ $I = .011 \text{ in.}^4$ $Z = .011 \text{ in.}^3$ $K = .57 \text{ in.}$ $W_1 = .035$ $W_2 = .037$ $A = .045 \text{ sq. in.}$ $I = .014 \text{ in.}^4$ $Z = .014 \text{ in.}^3$ $K = .57 \text{ in.}$ $W_1 = .042$ $W_2 = .044$
A = Area I = Moment of inertia Z = Section modulus K = Radius of gyration		W_1 = Weight without watertight packing strips, in lb. per foot run W_2 = Weight with watertight packing strips, in lb. per foot run

FIG. 3.—Dimensions of deeper channels. Aeromarine standards. Properties of structural shapes.

ment of Commerce in *Bulletin 14*. The same is true of Table 25 of riveted joints. In most cases the edges of the channels are flanged to present a flat base, as in Figs. 2, 3, and 4. For some work, however, the sides of the channels are straight and the bases are formed by other

flat-bottomed channels which fit inside the first, as in Fig. 5. In Fig. 6 the corner braces are shown in both elevation and section.

The proportions of the riveted joints of duralumin plates are given in Table 25. This table gives the proper rivet for the thickness of plate

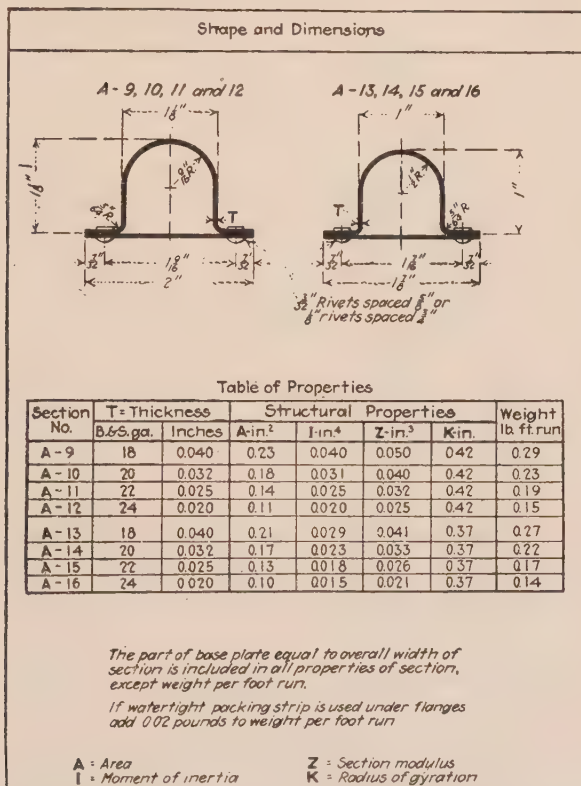


FIG. 4.—Dimensions of special channel. Aeromarine standards. Properties of structural shapes.

used, the spacing of the rivets and the sizes of the flanges and joints. In Table 25 the properties of the rivets themselves are shown.

The weight distribution diagrams, Figs. 7 and 8, are of interest. These charts divide the weight into four general divisions as shown by

the segments of the outer circle. Inside are the items which go to make up each division. The weights are very carefully calculated and

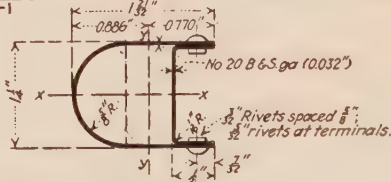
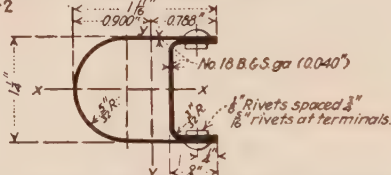
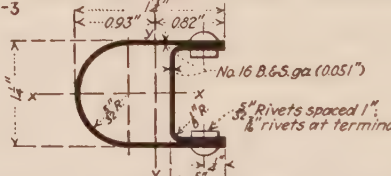
Shape and Dimensions	Properties
B-1  No. 20 B.S. ga. (0.032") $\frac{5}{8}$" Rivets spaced $\frac{5}{8}$" $\frac{1}{8}$" rivets at terminals.	$A = 0.19 \text{ sq. in.}$ $I_x = 0.049 \text{ in.}^4$ $Z = 0.079 \text{ in.}^3$ $K = 0.50 \text{ in.}$ $I_y = 0.054 \text{ in.}^4$ $Z = 0.060 \text{ in.}^3$ $K = 0.52 \text{ in.}$ $W = 0.29$
B-2  No. 18 B.S. ga. (0.040") $\frac{5}{8}$" Rivets spaced $\frac{5}{8}$" $\frac{1}{8}$" rivets at terminals.	$A = 0.25 \text{ sq. in.}$ $I_x = 0.062 \text{ in.}^4$ $Z = 0.100 \text{ in.}^3$ $K = 0.50 \text{ in.}$ $I_y = 0.069 \text{ in.}^4$ $Z = 0.077 \text{ in.}^3$ $K = 0.53 \text{ in.}$ $W = 0.36$
B-3  No. 16 B.S. ga. (0.051") $\frac{5}{8}$" Rivets spaced 1" $\frac{1}{8}$" rivets at terminals.	$A = 0.31 \text{ sq. in.}$ $I_x = 0.077 \text{ in.}^4$ $Z = 0.12 \text{ in.}^3$ $K = 0.49 \text{ in.}$ $I_y = 0.093 \text{ in.}^4$ $Z = 0.10 \text{ in.}^3$ $K = 0.54 \text{ in.}$ $W = 0.46$
B-4  No. 14 B.S. ga. (0.064") $\frac{1}{8}$" Rivets spaced $1\frac{1}{8}$" $A = \text{Area}$ $I = \text{Moment of inertia}$ $Z = \text{Section modulus}$ $K = \text{Radius of gyration}$	$A = 0.40 \text{ sq. in.}$ $I_x = 0.096 \text{ in.}^4$ $Z = 0.15 \text{ in.}^3$ $K = 0.49 \text{ in.}$ $I_y = 0.12 \text{ in.}^4$ $Z = 0.13 \text{ in.}^3$ $K = 0.54 \text{ in.}$ $W = 0.57$

FIG. 5.—Dimensions of double channel struts. Aeromarine standards. Properties of structural shapes.

the charts show the weight distribution in considerable detail. One is for the mail plane and the other for the flying boat.

The structural shapes, (Fig. 9 to 11) are a later development, and have been found very useful in floats, pontoons, and other constructions.

The extruded angle bulb is low in cost and requires only one row of rivets for the attachment of covering. It also avoids the use of "blind" riveting as with the U-sections, and being small in size it can be made in

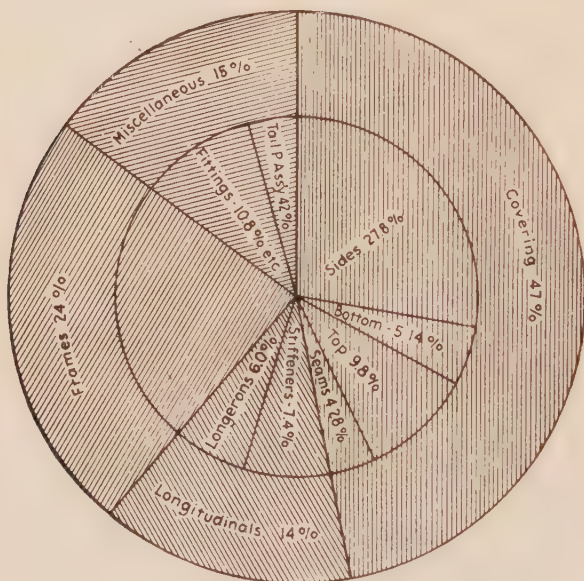
Shape and Dimensions	Properties
Shape F-1 Section A-A No 20 B & S Gage 0.032" Duralumin 1/8" Duralumin rivets	F-1 For use with Section A-1 Weight 0.09 lb
Shape F-2 Section A-A No 18 B & S. Gage 0.040" Duralumin 1/8" Duralumin rivets	F-2 For use with Section A-2 Weight 0.13 lb
Shape F-3 Section A-A No 18 B & S. Gage 0.040" Duralumin 1/8" Duralumin rivets	F-3 For use with Sections A-5 & 6 Weight 0.13 lb.

FIG. 6.—Dimensions of corner braces. Properties of structural shapes.

thicker sections without materially increasing the weight. The heavier section, combined with bulb on the free edge, makes it stand well in service. Its shape and thickness resists buckling and it can be bent to almost any shape desired in manufacturing. In Edo floats, for

example, the G-4 section (Fig. 9), is bent so that one length extends from chine to chine with two bends at the joint of the sides to the deck.

Another interesting detail of Edo construction is the gusset plate (Fig. 12). This is blanked in a die and can be made to very close



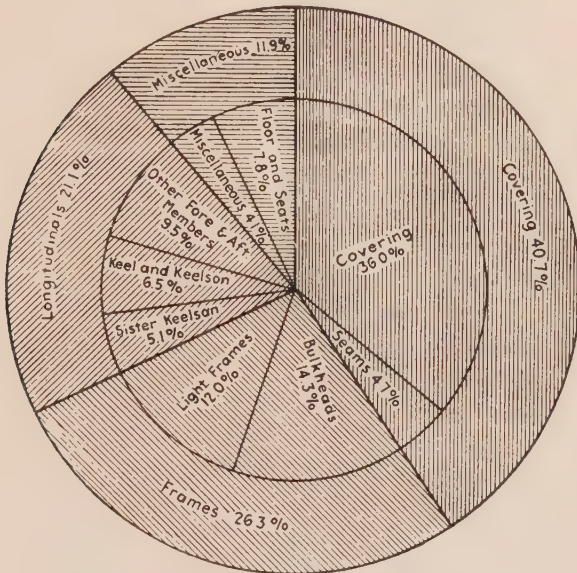
Coverings	127 Lb	47%
Frames	64 Lb	24%
Longitudinals	38 Lb	14%
Miscellaneous	29 Lb	15%
Total Weight,	268%	100%

Calculated from drawing number 17,813

FIG. 7.—Weight distribution of mail plane.

tolerances. It is used for the joint when two G-4 sections (Fig. 10), such as the frame and the stringer intersect. The gusset plate is slipped on the bulb angle of the frame, which is continuous, and riveted to the stringer which is cut to pass the frame member.

The bulb-angle section was developed for the definite purpose of being used in plate girder construction, where the angle is always riveted to the plate and where the large moment of inertia is required in one direction only. The Edo Aircraft Corporation uses them for



Covering	327Lb	40.7%
Frames	212Lb	26.3%
Longitudinals	170Lb	21.1%
Miscellaneous	96Lb	11.9%
Total Weight	805Lb	100%

Miscellaneous weight includes all seats, floors, fittings, etc integral with hull

FIG. 8.—Weight distribution of flying boat.

frames, stringers, and keelsons of floats or pontoons, and have also used them in combination with web plates and cover plates in the construction of wing beams. Figure 13 shows the use of these bulb sections in a rear wing beam for a flying boat built by this firm. These are practical construction designs that are in actual use.

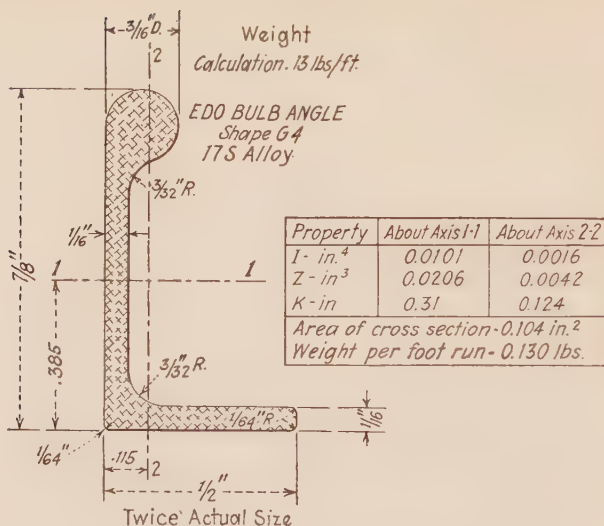


FIG. 9.—Bulb angle; shape G-4.

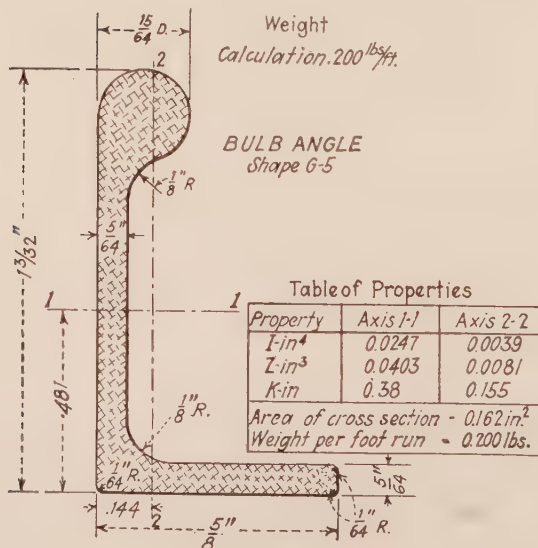


FIG. 10.—Bulb angle; shape G-5.

TABLE 24.—TABLE OF SHEAR AND BEARING VALUES FOR DURALUMIN RIVETS

Diameter of rivet	Shear in pounds	Bearing values for various thicknesses for sheets in brown and sharp gage-pounds											
		No. 6	No. 8	No. 10	No. 12	No. 14	No. 16	No. 18	No. 20	No. 22	No. 24	No. 26	No. 28
		0.162	0.128	0.102	0.081	0.064	0.051	0.040	0.032	0.025	0.020	0.016	0.0126
1/16	92	.....	.....	.....	.....	300	239	187	150	117	94	74	59
3/32	207	.....	.....	.....	468	450	358	281	225	176	140	112	88
1/8	368	.....	.....	955	758	600	478	375	287	235	187	149	118
5/32	575	1,895	1,495	1,190	947	748	597	468	359	292	236		
3/16	828	2,280	1,800	1,435	1,137	900	717	562					
1/4	1,470	3,040	2,400	1,910	1,516	1,200	955						
5/16	2,300	3,800	3,000	2,390	1,895	1,500							
3/8	3,440	4,560	3,590	2,870	2,275								
1/2	5,880	6,060											

Based on shear strength of 30,000 pounds per square inch.

Bearing strength of 75,000 pounds per square inch.

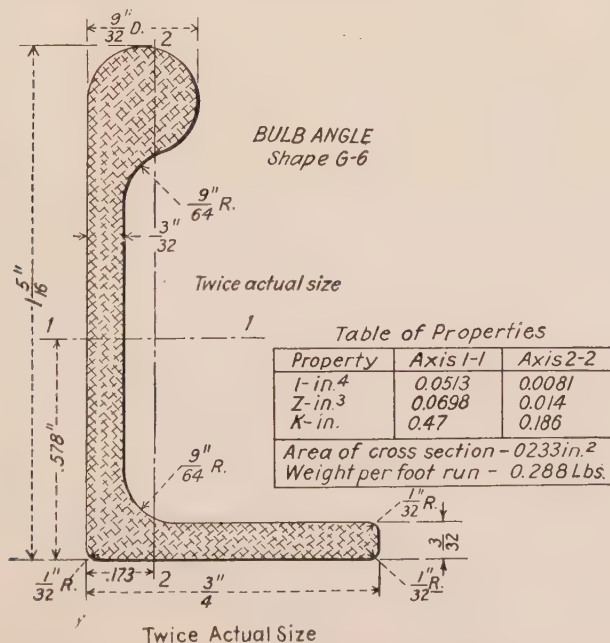


FIG. 11.—Bulb angle; shape G-6.

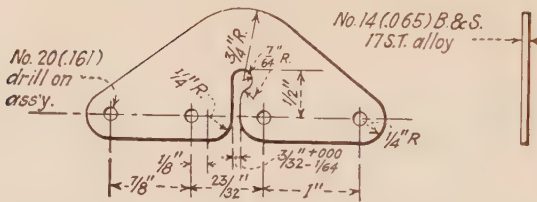


FIG. 12.—Gusset plate.

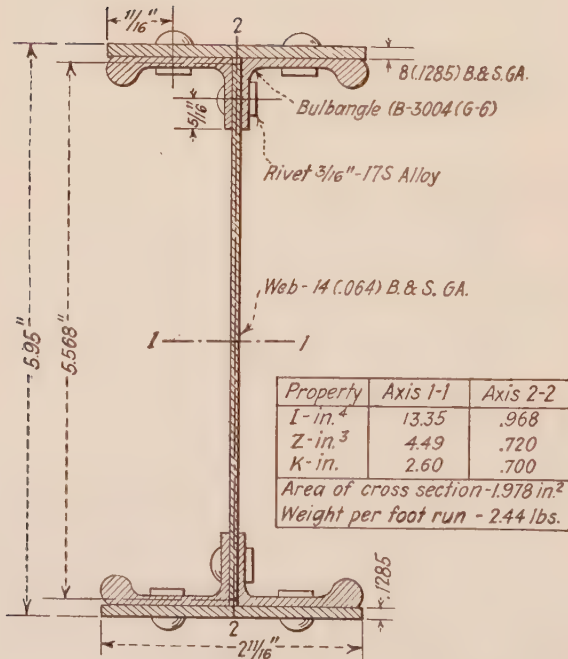


FIG. 13.—Rear wing spar.

ALUMINUM-ALLOY CASTINGS

The Bohn Aluminum and Brass Corporation give the following data as to the properties of Bohnalite when cast under different conditions and for different uses:

Pistons for automobile, truck, bus, and aircraft engines:

Bohnalite "J" permanent molded

Tensile strength, pounds per square inch.....	35,000 to 50,000
Elongation, per cent in 2 inches.....	0.5
Elastic limit, pounds per square inch.....	25,000 to 30,000
Brinell hardness number.....	125 to 160
Specific gravity.....	2.90
Weight per cubic inch, pounds.....	0.105
Coefficient thermal expansions, per degree Centigrade.....	0.000025
Coefficient thermal conductivity, c.g.s. units.....	0.38
Solidification range, degrees Fahrenheit.....	1,160 to 1,020

Aircraft castings:

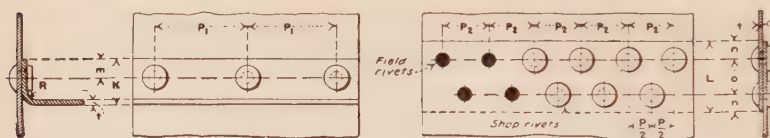
Bohnalite "B" sand cast

Tensile strength, pounds per square inch.....	28,000 to 45,000
Elongation, per cent in 2 inches.....	1.10
Elastic limit, pounds per square inch.....	18,000 to 27,000
Brinell hardness number.....	60.90
Specific gravity.....	2.78
Weight per cubic inch, pounds.....	0.101
Coefficient thermal expansions, per degree Centigrade.....	0.000024
Coefficient thermal conductivity, c.g.s. units.....	0.32
Solidification range, degrees Fahrenheit.....	1,190 to 1,020

PLYWOOD CONSTRUCTION IN AIRPLANES

While nearly all airplane builders in this country now use metal in fuselage construction, plywood still plays a large part in other portions of the plane structure. Many use plywood in building up wing beams and in forming the leading edge of the wings, where it lends itself to maintaining the desired form and makes a good backing for the cloth covering. It is also used in rib construction, in fuselage covering, and in other places.

TABLE 25.—PROPORTIONS OF RIVETED JOINTS OF DURALUMIN PLATES



Thickness of plate- <i>t</i>		Rivet <i>D</i> , inches	Rivet spacing		Location of rivets			Sizes of flanges and joints		
B. & S.	Inches		<i>P</i> ₁	<i>P</i> ₂	<i>m</i>	<i>n</i>	<i>o</i>	<i>k</i>	<i>R</i>	<i>L</i>
6	.162	1/2	3-0	2-0	5/8	5/8	1-1/4	1-1 1/16	5/16	2-1/2
8	.128	3/8	2-1/4	1-1/2	7/16	1/2	1-0	1-1/4	1/4	2-0
10	.102	5/16	1-7/8	1-1/4	3/8	7/16	7/8	1-0	3/16	1-3/4
12	.081	1/4	1-1/2	1-0	5/16	3/8	3/4	7/8	5/32	1-1/2
14	.064	3/16	1-1/8	3/4	1/4	5/16	5/8	5/8	1/8	1-1/4
16	.051	5/32	1-0	5/8	1/4	5/16	5/8	9/16	1/8	1-1/4
18	.040	1/8	3/4	1/2	7/32	9/32	9/16	1/2	3/32	1-1/8
20	.032	3/32	5/8	3/8	3/16	1/4	1/2	7/16	1/16	1-0
22	.025	3/32	5/8	3/8	3/16	1/4	1/2	7/16	1/16	1-0
24	.020	3/32	5/8	3/8	3/16	1/4	1/2	7/16	1/16	1-0

Supplementary notes:

(a) When two plates to be riveted differ in gage by one place in the table, proportion joint to lighter plate.

(b) When two or more plates to be riveted differ in gage by more than one place in the table, proportion joint to mean gage, taking nearest lighter gage in case of odd number.

(c) Rivet spacing to be governed by rivet diameter, rather than by gage of plate.

(d) In joints of minor importance rivet spacing *P*₁ may be doubled.

TABLE 26.—TENSILE TESTS OF THREE-PLY AIRPLANE HASKELITE
(Strengths are given in pounds per inch width)

Faces	Core	Angle between face grain and axis of tension degrees	Normal condition	Boiled three hours, tested		Soaked in 2.6 per cent salt solution 12 days; wet	Soaked in machine oil 19 days
				Still wet	After drying		
$\frac{1}{16}$ inch Birch	$\frac{1}{12}$ inch Redwood	0	2,175	1,512	2,090	2,037	2,586
		22½	1,184	535	883	436	1,051
		45	572	248	500	256	499
		67½	458	305	429	407	473
		90	636	702	587	510	396
$\frac{1}{16}$ inch Birch	$\frac{1}{12}$ inch Poplar	0	1,923	1,318	1,741	1,251	1,753
		22½	648	406	579	383	640
		45	523	174	488	321	436
		67½	489	237	417	278	538
		90	1,044	700	902	923	1,158
$\frac{1}{8}$ inch Birch	$\frac{1}{16}$ inch Mahogany	0	1,204	867	1,124	1,168	1,581
		22½	572	327	538	423	724
		45	464	227	430	272	461
		67½	435	239	549	340	639
		90	697	364	594	447	801
$\frac{1}{8}$ inch Birch	$\frac{1}{16}$ inch Poplar	0	1,324	887	975	953	1,496
		22½	577	276	535	344	669
		45	476	176	421	229	482
		67½	573	268	586	376	618
		90	910	508	807	705	855

Two builders, one of them very well known, is also using plywood in building the fuselage. One, Lockheed, depending on the plywood for his fuselage strength, as can be seen by noting the monocoque construction on page 411, and the other, by using plywood as an auxiliary strengthening member, adding its strength to that of a wooden trussed framework underneath; the method being illustrated on page 410.

Details of the method of building up wing beams from plywood are shown in Fig. 14. The upper and lower members are usually of spruce

TABLE 27.—TENSILE STRENGTH OF SCARF JOINTS

Scarfs across face grain (as at A). Specimens 2" wide and 40" long of $\frac{1}{4}$ "—3 Ply Haskelite gum faces fir core longitudinal face grain, each having 4 scarfs 5" long bevelled by hand, glued with yellow albumen glue; all were cut from a single scarfed panel and tested in tension; some specimens twice.

Of thirty tests, 23 failures were at scarf joints, and 7 not at such joints. Their strength in pounds per inch width was as follows.

Number and location of failures	Strength		
	Max.	Min.	Mean
23 at scarf joints.....	1,590	1,000	1,300
7 not at scarf joints.....	1,580	1,180	1,380

The average thickness of these specimens was 0.262", max. 0.277", and minimum 0.250".

Scarfs across core grain (as at B). Specimens were just like the above except that the core grain was longitudinal and was cut by the four scarfs of each specimen. Their strength in pounds per inch width was:

Number and location of failures	Strength		
	Max.	Min.	Mean
19 at scarf joints.....	1,390	720	1,000
12 not at scarf joints.....	1,380	720	1,060

The average thickness of these specimens was 0.262", maximum 0.278" and minimum 0.243".

Scarfs on $\frac{5}{16}$ " Haskelite are of ample strength when the width of bevel is 3" instead of 5". Commercial scarfs are not made across the core grain because of the difficulty of holding the sharp edge parallel to the face grain in the process of scarfing.

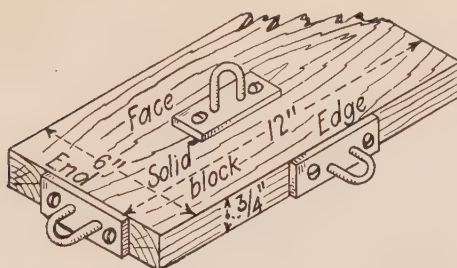


A



B

TABLE 28.—SCREW HOLDING STRENGTH OF WOODS



Position	Species, grade used in lumber cores	Number of tests	Tensile strength of two screws (common, steel, flat head, 1 inch—No. 8, in holes made with No. 36 twist drill)—pounds		
			Max.	Min.	Mean
Face	Chestnut.....	6	460	270	400
	Basswood.....	8	670	380	550
	Poplar.....	6	820	570	720
	Gum.....	6	1,060	950	1,010
	Oak.....	6	1,700	1,400	1,560
	Maple.....	4	1,860	1,640	1,790
Edge	Chestnut.....	6	830	330	480
	Basswood.....	8	850	500	670
	Poplar.....	6	1,170	850	1,020
	Gum.....	6	1,140	970	1,030
	Oak.....	4	1,910	1,540	1,710
	Maple.....	4	1,940	1,670	1,820
End	Chestnut.....	6	370	140	250
	Basswood.....	8	340	160	270
	Poplar.....	6	620	340	440
	Gum.....	6	570	300	480
	Oak.....	6	870	530	680
	Maple.....	4	1,250	810	1,030

while the sides are of plywood, mahogany being considered best for the plywood in most cases. The strength of the beam can be varied at different points by varying the number of plies in the sides. Makers of plywood also supply it with hard aluminum sheet securely cemented to one face when desired.

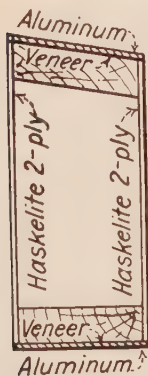


FIG. 14.—Wing beam of plywood.

Several characteristics of the plywood known as "Haskelite," are shown in Table 26. This shows the kind of wood used, the angle of the different plies, the strength in normal condition, and when subjected to water and oil for various tests. Table 27 shows the strength of scarfed joints and under different conditions. Table 28 gives a number of tests as to the holding power of screws in plywood and should be useful when considering the use of this material for any purpose.

BALSA WOOD IN AIRCRAFT¹

Balsa wood grows in the West Indies and in Central and South America. The trees grow at a very rapid rate, records showing that they attain their height in 1 year, which is approximately 36 feet, and that for the first 5 years there is an annual growth in diameter of 5 inches, resulting in a tree at the end of the fifth year of 36 feet height and 25 inches diameter.

The tree in appearance resembles the North American cottonwood, the bark being fairly smooth, but the wood looks quite like pine. The leaves are very large on a young plant, often 2 and 3 feet across, growing smaller as the tree grows older. The wood is made up of very thin barrel-shaped cells filled with air which are sealed by nature, giving it an extremely spongy texture. Two interesting and important properties are its flexibility and elasticity. The strength of the wood is derived from the cellular structure, as there is almost no lignification in the tissues, but the wood is practically cellulose. Approximately 92 per cent of the volume of the wood consists of these air-filled cells and the remainder, 8 per cent, of woody substance.

¹ By G. L. WEEKS, Jr., New York, N. Y.

All balsa wood used in airplane construction should be kiln-dried. This method is necessary, as air-drying is a very slow process, requiring about three months to remove the unnecessary moisture from the material and leave the 8 to 12 per cent water content which is desired for practical purposes. Kiln drying on the other hand obtains the same result in a more efficient and satisfactory manner in the much shorter time of ten days to 2 weeks.

For some purposes, such as insulation and waterproofing, balsa wood can be and is very easily impregnated with paraffin. This is done to seal the air cells. Impregnation is the most efficient method of treating the wood and achieving the desired result, but it also may be coated with paraffin, as this process also does the work.

Comparison with Other Woods.—Balsa is interesting because of its extremely light weight. In fact, so far as known, there is but one other wood, the pond-apple (*Anona*), that weighs less, but this is of little value to the commercial world. In commercial use, balsa is the lightest wood, as the following comparison will show:

Balsa, 7.3 pound per cubic foot; cork, 13.7; Missouri corkwood, 18.1; white pine, 23.7; spruce, 25.5; poplar, 27.4; cypress, 28; maple, 43; mahogany, 45; white oak, 46.8; *lignum vitæ*, 71; ebony, 73.6.

Tests have shown that even though balsa is very light in weight, its strength is about one-half of that of spruce. Therefore balsa may be used in certain places where strength is not the all-important factor but where lightness is. A comparison with spruce is given in the table in the adjoining column.

The specific gravity of balsa when free from moisture is from 0.11 to 0.12.

Use of Balsa Wood in Airplanes.—The use of balsa wood in the construction of airplanes is beyond the experimental stage. The many severe tests, such as Colonel Lindbergh's New York-to-Paris flight, Chamberlin's New York-to-Germany flight, and many other exploits, as well as Army, Navy, and air-route machines, have proved beyond a doubt that balsa wood is used as efficiently as spruce or other woods where it is an important part of the machine and lightness as well as an average amount of strength is required.

Balsa wood is used in all types of airplanes, in such parts as the outboard struts, fillets, fuselage for stream lining, wing ribs, wing tips, strut fairings, and shaping fuselage.

	Spruce: red, white, and Sitka	Balsa
Strength in bending—modulus of rupture, pounds per square inch.....	3,850-5,820	2,357
Maximum crushing strength in compression—parallel to grain, pounds per square inch.....	1,800-2,920	2,317
Fiber stress at elastic limit—strength in compression perpendicular to grain, pounds per square inch...	279-368	202
Stiffness, modulus of elasticity in bending, thousands of pounds per square inch.....	798-1,215	510
Shearing strength parallel to grain, pounds per square inch.....	569-777	351

Characteristics of Balsa.—Where steel tubing is used on landing gear, balsa is used successfully. It is machined easily, thus a material saving in spruce is obtained. By using balsa as fairing, the saving in spruce is equivalent to the amount required to make three-wing spars. It is therefore worthy of consideration by the designers and engineers when constructing new types of airplanes to give serious thought to balsa wood.

Balsa wood veneer may also be considered. Wing braces so constructed and cut as to form a lattice web are now used in planes. Floor boards of balsa veneered with thin layers of composition material are also used in the construction of present-day planes. In the wing-rib construction of the Bellanca planes balsa wood is used as a filler. On the wing tips a strip of balsa is fixed to give the wing a rounded tip.

On the landing gear, the "pants part" is all balsa fairing around the metal construction in a graceful stream-lined fashion. In the fuselage where steel tubing is the main structure, balsa wood is faired and taped to the cross-members to give shape and stream line. The best method of treating balsa wood for fairing and other exposed parts is taping and then using about five coats of dope. A saving of from 20 to 50 pound per plane is worth considering.

TESTING GLUES AND GLUED JOINTS

A recommended method of testing glued joints is to make test pieces $\frac{3}{4}$ inch thick, 2 inches wide and $1\frac{3}{4}$ inches long and glue them together with the ends projecting $\frac{1}{4}$ inch leaving $1\frac{1}{2}$ inches in contact. The joint should be held under pressure for 15 hours and allowed to stand for 6 days before testing in order to secure the best results. Such a joint should stand a minimum pull of 2,000 pounds and should average about 2,400 pounds. With good glue the wood should fail rather than the glue in the joint. This refers to blood albumen glue, made from animal blood and chemicals. The glue pots should be kept clean and no old glue allowed to accumulate.

The usual pressure for the joint should be from 200 to 400 pounds.

SOFT SOLDERS AND THEIR APPLICATION¹

Soldering is the process of joining two metals by the application of a molten alloy. It differs from welding in that the base metals are not fused in the process, and it differs from brazing in the nature of the alloys used to make the joint. Soft solders of the tin-lead alloys are in reality metallic cements possessing the property of adhering only to metals with which they are capable of alloying. The solder penetrates into the base metal, and when force is used to separate the two soldered surfaces the break will occur in the solder between the surfaces. The thicker the layer of solder, the easier it will break. Closely fitted surfaces, with a minimum of solder, are therefore essential for the best soldered joints.

The simplest form of solder is a mixture of tin and lead. Tin is not employed alone as it is expensive, and requires more skill in handling. It flows easily, and spreads beyond the surfaces to be soldered. Lead, on the other hand, is difficult to work, does not flow easily, and will not hold to the base metals. The common commercial solders called "half and half" do not always contain half proportions of each metal, and when too much lead is used to make a cheap solder, or when zinc and antimony is present, great difficulty is likely to be experienced in making satisfactory soldered joints.

Pure lead has a melting point of 619° F., and pure tin melts at 450° F. Mixing two metals into an alloy, however, lowers the melting point, and it is possible by making the right proportions of each alloying metal to reach the "eutectic" alloy whose melting point is the lowest possible. This tin-lead alloy is found to have a combination of 68 per cent of tin and 32 per cent of lead, and has a melting point of 356° F. By alloying other metals in turn

¹ *American Machinist*, Feb. 3, 1927.

with the tin-lead alloy it is possible to lower the melting point still further. Bismuth and cadmium, with melting points of 507 and 608° F. respectively, are used for this purpose. Very low melting solders are made up of alloys of tin, lead, bismuth, and cadmium, which are used for soldering on soft metals. An alloy has been made with a melting point of 158° F., and will melt readily in hot water. This type of solder is used in connection with automatic sprinkling systems.

Solder should be chosen to suit the nature of the base metals and of the conditions of the work. A solder containing 85 per cent of tin and 15 per cent of lead, melts at 406° F., is free flowing, and is used for general soldering in electrical work. Another solder in general use contains 42 per cent of tin, and 58 per cent of lead. The melting point of this alloy, however, is 458° F., and it flows and sticks with somewhat more difficulty. Solder should always have a lower melting point than that of the base metal.

Solder is furnished commercially in various forms, the most common of which are wire, bars, ribbon, and ingots. It is also made up as hollow wire and filled with an acid or rosin flux. Having determined the best types and grades of solder for the work of the shop, it is important to see that this material is furnished regularly for the jobs. Solder for shop use should not be bought indiscriminately from local commercial stocks without full assurance of its content.

Cheap solders, or home-made solders made up in the shop without chemical analysis, are liable to contain impurities that make them unsuitable for use. Any trace of zinc in solder makes it almost worthless. It makes the solder sluggish, and the molten alloy runs in irregular waves and lumps. Antimony makes solder bright in color, but when much of this metal is present the solder is sluggish and brittle. Copper, aluminum, iron, and sulphur are also detrimental to all soft solders. Money saved through buying cheap solders is usually lost by the increased cost of the actual work of soldering the parts.

Fluxes are necessary for all soldering work, since a thin film of oxide is formed on the metals by the heat, and a flux is required to prevent or dissolve this oxide. The most common flux is a solution of zinc chloride, made by dissolving metallic zinc in muriatic acid. But where the acid flux is undesirable as for some electrical parts, common rosin, or rosin and alcohol, is sometimes used. For the latter $\frac{1}{2}$ pound of rosin is dissolved in about a quart of alcohol.

To obtain good soldered connections, the surfaces to be soldered must be cleaned thoroughly, and the iron must be kept hot enough to heat the surfaces and make the solder flow freely. A small soldering iron loses its heat too rapidly, and should not be used except where space will not permit the use of a large iron.

CHARACTERISTICS OF SILVER SOLDERS¹

Silver solders are high-melting-point brazing solders employed for important joints where strength and resistance to high temperatures and corrosion are important. They are more expensive than common solders and ordinary brazing metals, but are widely used because of their high strength. Typical uses are for joining gasoline and oil lines on airplanes where heavy vibration is encountered, and for the gas piping on electric refrigerators where the prevention of leaks is of utmost importance. Joints made with good silver solders are often stronger than the original metal of the parts.

The range of melting points for silver solders is from 1300 to 1600° F. The melting point of pure silver is 1761° F., but this is lowered by the addition of copper, zinc, and sometimes cadmium. The solders contain a high percentage of copper, which may be considered as the base metal of the solder since the melting point is higher than that of silver. In general, the solders containing high percentages of silver flow at the lower temperatures, though this is not always true as the low melting point may be obtained by larger additions of zinc and cadmium. Silver solders may be considered brasses with the addition of silver as a hardener and toughener, but this designation is not exact because in some cases the silver content may be very high, even reaching to as high as 80 per cent. Some solders may have only copper and silver, while others may contain the four metals.

Grades by Melting Point.—Silver solders may usually be obtained in grades according to the melting point, the latter varying in steps of 25° F. The lower melting point solders are generally silvery-white in color, gradually changing to brass yellow in the grades having the higher melting points. The range of melting point should be selected according to the metal for which it is intended to solder, but since the melting point is not a secure guaranty of quality the recommendations of the maker should also be considered. It is often important, also, that the color of the solder match the color of the parts, especially if the latter are made of nickel, Monel metal, or bronze.

A fine quality of "easy flowing" solder, rich in silver, and having a melting point from 1325 to about 1450° F., is employed extensively for soldering copper, nickel, and Monel metal tanks, gas lines, radio parts, and airplane fuel and oil pipes. For brass work where the color is to be matched, and where a lower-cost solder is desired, higher melting point solders of yellow color are used. For soldering iron and steel a temperature of about 1550° F. is required to make a good bond.

¹ For the data given we are largely indebted to HANDY and HARMAN, *American Machinist*, Feb. 28, 1929.

The blow torch is always used for silver soldering, since the melting points are too high for ordinary soldering methods. The parts to be soldered should first be heated at and near the joint, the latter being brought quickly to the desired temperature (cherry red to bright red) when the parts are hot. The silver solder is then melted under the flame and caused to flow along the joint. The surfaces to be soldered must be clean and smooth. The joints should fit closely, and be held together firmly while being soldered. Borax is used as a flux, either powdered or mixed with water or alcohol. Both the joint and the solder should be covered with the flux to protect the metal against oxidation.

Temperatures Employed.—Care should be used not to overheat the work. The principal metals which are silver soldered begin to melt at temperatures, degrees Fahrenheit, approximately as follows:

Steel.....	2500	Bronze (90-10).....	1830
Monel metal.....	2480	Low brass	1740
Copper.....	1980	High brass.. ..	1630
Nickel silver.....	1950	Extruded brass.....	1580

The parts should never approach these temperatures, as prolonged heating at high temperatures tends to give a coarse grain and poor structure to the work. For example, Monel metal should not be heated above 1450° F., although it melts at a much higher temperature.

Silver solder is usually marketed by the Troy ounce in the form of sheet, strip, wire, or filed. The sheet comes in rolls, and the strip in short lengths of varying widths. The usual thickness of sheet and strip is about 0.032 inch. Filings, or powdered solder, is sold in cans of varying screen sizes.

A good quality of silver solder produces a joint that is malleable and ductile, capable of withstanding vibration. Resistance to corrosion is a characteristic of all silver solders, which makes them valuable for airplane work, tanks, and dairy and food-products machinery. Silver solders also have the characteristic of uniformity of flow, whereas ordinary brazing metals are apt to show pittings. A silver-soldered joint is therefore considered more reliable and secure against leakage for tank and pipe work. The electric conductivity of these solders is generally higher than that of copper, which makes them valuable for making joints on radio and other electrical parts.

RUST-PROOFING PROCESSES¹

Udylite.—Udylite is a rust-proofing process named after its inventor, Martin J. Udylite. The process consists in coating the surface to be treated

¹ For the information given we are indebted to the Udylite Process Co., and the Grasselli Chemical Co., *American Machinist*, June 2, 1927.

with cadmium in such a way that the coating is alloyed with the base metal. Udylite coatings are claimed not to chip, check, or crack.

Udyliting is essentially a class of electro-plating, supplemented by a baking process. Iron or steel articles are given a coating varying in thickness from 0.0001 to 0.001 inch. It can also be applied to other metals. The time required for plating is from 1 to 10 minutes. The article is then baked for a period of from 2 to 3 hours at a temperature of from 300 to 400° F. The baking process is intended to cause the cadmium to penetrate the steel and form an alloy case. Articles coated by the Udylite process have a thin skin of cadmium base-metal alloy, and an external skin of pure cadmium. On bending a sheet of steel that has been Udylited there should be no indication of cracking in the surface. Udylited articles are buffed with a soft, unstitched wheel. The color is a flat-white, but when polished is very nearly like that of silver. Other metals may be plated over the Udylite coating if desired, and nickel over Udylite is claimed to stand up ten times longer than if deposited alone or over copper plate.

The principal equipment for the Udylite process consists of asphaltum-lined tanks fitted with rods and connections, and a standard plating dynamo as for electroplating. Carbon electrodes and a specially prepared cadmium solution are used. There are also provided the usual metal-cleaning solutions, scrubbing tank, hot- and cold-water tanks, acid-dip tank, and a baking oven in which a temperature of about 350° F. can be maintained. Air at 5 pounds pressure is also used for agitating the solution when a bright deposit is desired. The only difference in the equipment over that for electroplating is that the anodes and solutions are different, and the baking oven is added.

One pound of cadmium salts will cover 134 square feet of surface if applied 0.0002 inch in thickness. This depth of coating is claimed to be several times as resistant to corrosion as ordinary commercial galvanizing of 0.001 inch in thickness. The thin coat of cadmium required by this process does not clog threads or destroy close fits as is the case with the heavier coats of zinc needed for the same protection. Paints and varnishes are claimed to adhere well to Udylited surfaces. Udylited steel articles are claimed to have stood the salt-spray test for 1,860 hours without rusting, while ordinary nickel plate showed indications of rust in 2 hours and peeled in 40 hours.

Cadalyte.—The Cadalyte rust-proofing process is essentially the electro-plating of cadmium on a base metal. The chief points claimed for the process are that the solution is easily prepared and will not deteriorate rapidly, and that it will produce an effective coat of cadmium in a short time.

Cadmium is a soft, ductile metal which does not form basic salts as readily as zinc, and is therefore less subject to corrosion than zinc. It is above iron in the electromotive series, and is thus a better rust-proof coating for iron or steel than either tin or nickel. Any metal covering that is below

iron in the electromotive series only protects the iron as long as the coating is intact, and will accelerate corrosion if the coating is broken or pitted.

The material to be Cadalyted is cleaned in the usual manner, and the equipment for the process is similar to that for other classes of electroplating. Cadmium anodes only should be used, and they should be sufficient in surface area to equal the maximum surface of the articles to be plated at any one time. A high-current density is used in the plating bath, and at the rate of 30 amperes per square foot about 0.001 inch of plate thickness can be deposited in 10 minutes. The voltage is regulated so that the current flowing will produce a slight evolution of gas at the work. At this point the maximum rate of plating is attained, and the brightest deposit produced. Increased rates of deposit can be obtained satisfactorily by increasing the voltage if the solution is agitated.

In a Cadalyte plating bath all of the cadmium deposited on the work is taken from the anodes. This results in a constantly uniform composition of the solution. The solution does not decompose readily upon contact with the air. No heating is required, although it will operate satisfactorily at temperatures up to 130° F. Cadalyte solutions do not need special reagents, and any mechanical loss is replaced by the addition of more of the same composition. The coating of cadmium produced by the Cadalyte process is dense, ductile, and adherent, and presents a somewhat polished appearance when removed from the bath.

A Cadalyte coating is claimed to give a corrosion resistance as great as a plate of zinc several times as thick. This fact makes it especially valuable for the rust-proofing of bolts, screws, and nuts, where a thick plate would require undersized threads or rethreading. Cadalyte coating, moreover, is especially resistant to salt-water corrosion, and is therefore useful for marine work. Cadalyte coating can also be used as a flash for nickel plating, thereby combining the protective properties of cadmium with the high polish that can be obtained on nickel.

CHARACTERISTICS OF STAINLESS STEELS¹

Stainless steel is essentially a steel containing an appreciable amount of chromium. It was first produced in America in 1914, under the Brearley Patent. This original composition, of which a typical analysis is: Carbon 0.35 per cent and chromium 13.5 per cent, still finds its greatest use in the cutlery industry, and is designated as Sterling "Type A" stainless steel. As supplied from the mill, it has a Brinell hardness of 325 and is machinable.

¹ For the information given we are indebted to the Firth-Sterling Steel Co., *American Machinist*, Sept. 29, 1927.

In this condition its tensile strength is about 150,000 pounds per square inch minimum, with a minimum elongation of 12 per cent, and a reduction of area of 40 per cent. When hardened by oil quenching at 1750° F., and drawing at 450° F., it has a Brinell hardness of about 500, with a tensile strength of 240,000 pounds per square inch, minimum, an elongation of 4 per cent, and a reduction of area of 8 per cent. When air cooled from 1825° F., and drawn at 450° F., its Brinell hardness is about 450, and its tensile strength is 220,000 pounds per square inch, minimum, and elongation of 6 per cent. When hardened, ground, and polished, this steel has great resistivity to corrosion.

The success of stainless steel in the cutlery industry led to its adaption for various uses in the entire field of manufacturing. The fact was soon apparent, however, that the application of one type was incapable of meeting all the requirements of many various purposes. Modifications had to be made to improve certain physical properties or to overcome limitations. The dental- and surgical-instrument industry called for a stainless steel capable of greater hardness. To meet this demand, another type was developed in which maximum hardness is obtained with a loss of some of the corrosion resistance by increasing the carbon content of the original "Type A" and keeping the chromium content the same. A typical analysis of this steel is: Carbon 0.80 per cent, chromium 13.5 per cent. This type of steel is also used for scale pivots, ball bearings and ball races, and other parts requiring extreme hardness. Stainless steel of this composition is forged at temperatures between 1700 and 2000° F., and is annealed at from 1625 to 1675° F. It is hardened at a temperature of from 1800 to 1900° F., and the temper is drawn to meet the requirements.

To meet further the requirements of cutlers, another stainless steel was developed, which has both a high-carbon and a high-chromium content. This steel, which was designated as "Type B," has a typical analysis of: Carbon 0.65 per cent and chromium 16.5 per cent. The heat treatment of this steel is practically the same as that for the 13.5-per cent chromium type, but its Brinell hardness, when hardened, is somewhat lower, being about 550 as compared with 625 for the 13.5-per cent steel.

All of these types of stainless steels require heat treatment, with subsequent grinding and polishing, to obtain their stainless qualities. The call for a stainless steel that would eliminate the necessity for hardening and grinding, led to the development of still another type which is stainless without heat treatment, is readily machinable, and has exceptionally good physical properties. A typical analysis is: Carbon 0.10 per cent, chromium 12.5 per cent. This stainless steel is used for steam-turbine blades, and for such machine parts as pump rods, shafts, and soldering points. While heat treatment is not necessary to develop stainless properties in this steel,

the physical properties can nevertheless be improved by oil quenching at 1800° F., and then drawing at various temperatures up to 1100° F. The hardness is greatly influenced by slight variations in drawing temperatures. As supplied from the mill, this stainless steel has a Brinell hardness from 200 to 240, and a minimum tensile strength of 100,000 pounds per square inch, with an elongation of 20 per cent and a reduction in area of 60 per cent, minimum. When oil quenched from 1800° F., and drawn at 450° F., the steel has a tensile strength of 190,000 pounds per square inch, minimum, with an elongation of 15 per cent., minimum. Drawing at 1100° F. reduces the tensile strength to 150,000 pounds per square inch, but increases the elongation to 20 per cent. When annealed, this 12½-per cent chromium steel is readily machinable.

All of the standard chromium stainless steels can be forged, but to meet the requirements of manufacturers of drop forgings, a soft malleable type of stainless steel was developed which could be formed into intricate shapes with approximately the same ease as low-carbon steel, and which does not possess the air-hardening properties common to the other types. The stainless steel developed to meet the requirement contains about 16 per cent of chromium and 0.08 per cent of carbon. This steel can be forged readily, and is highly resistant to rust and corrosion. It is forged at a temperature of 1600 to 2000° F. It can also be hardened if required by quenching from a temperature of 1775 to 1825° F.

HEAT-RESISTANT ALLOYS¹

Heat-resistant alloys are alloys that will withstand continuous heating at high temperatures without serious oxidation. They are employed for carburizing boxes, furnace parts, resistance wires for electrical heating apparatus, automotive engine valves, spark plug points, and for many other articles subject to continuous or intermittent heating. They also generally have high resistance to the corrosive action of acids and alkalies, and some of the alloys are closely related to the group of acid-resistant metals.

The heat-resistant alloys are in general based on nickel and chromium, but may contain amounts of iron up to 60 per cent or more. They may also contain small percentages of manganese, silicon, or other elements to give other properties such as great hardness, increased tensile strength, or additional acid-resistance.

Since chromium and nickel are both expensive metals, the proportion of iron may be increased in the grades which are not expected to withstand the maximum temperatures. The standard alloy for high-temperature

¹ *American Machinist*, Oct. 4, and Nov. 22, 1928.

resistance wire, for example, contains about 80 per cent of nickel and 20 of chromium. This will withstand continuous heating up to 2100° F. But for average conditions, where the operating temperatures are only about 1800° F., iron may be added up to the extent of about 25 per cent and the content of chromium and nickel reduced, with consequent economy of cost. Heat-resistant alloys are marketed under many trade names, and most makers produce their materials in varying grades to meet the service conditions.

Another class of metals sometimes grouped with the heat-resistant alloys is the high-chromium iron and steel belonging to the "rustless" and "stainless" groups. These alloys, when employed for heat-resistance, usually contain more chromium than the ordinary stainless steels. They also contain only a very low percentage of carbon.

Atha's 2,600 Alloy.—Atha's 2,600 Alloy is the trade name of a heat-resistant and corrosion-resistant alloy containing approximately 22 per cent of nickel, 8 of chromium, 1.75 of silicon, 1 of copper, 0.70 of manganese, 0.50 of carbon, and the remainder iron. It is also resistant to the action of many acids, and is non-magnetic. It is a product of the Crucible Steel Company of America, New York. Atha's 2,600 Alloy can be hot rolled into bars and sheets, cold drawn into wire, forged, or cast. It can be machined readily, but not as easily as ordinary steels. It is annealed by quenching in water from a temperature of 1200 to 1600° F. The tensile strength, annealed, is from 95,000 to 125,000 pounds per square inch, and the elongation 25 to 35 per cent. The specific gravity is 7.95, and it weighs 0.29 pounds per cubic inch.

Nichrome.—Nichrome is the general trade name of a group of alloys produced by the Driver-Harris Company, Harrison, N. J., and employed for carburizing boxes, resistance wires, and a wide variety of other uses. The standard grade of casting Nichrome for carburizing boxes contains 67 per cent of nickel, 16 of chromium, 12 of iron, and 1 of manganese. It has a tensile strength of 64,000 pounds per square inch. The melting point is 2460° F., and it will resist oxidation and scaling at temperatures up to 1650° F. A grade of Nichrome used for resistance wire contains 60 per cent of nickel, 12 of chromium, 26 of iron, and 2 of manganese. The tensile strength is 100,000 pounds per square inch. The weight is 0.294 pounds per cubic inch. Other grades used for various purposes are marketed. Nichrome IV contains 80 per cent of nickel and 20 of chromium, and will resist oxidation at continuous temperatures up to 2100° F. The tensile strength is 120,000 pounds per square inch, melting point 2535° F., and weight 0.306 pounds per cubic inch.

Ascoloy.—Ascoloy is the trade name of a heat-resistant and corrosion-resistant alloy produced by the Alleghany Steel Company, Brackenbridge,

Pa. It is a chromium-iron alloy made in the electric furnace, and contains from 12 to 16 per cent of chromium, 0.50 per cent each of manganese, nickel, and silicon, and below 0.12 per cent of carbon. It is manufactured in various grades in billets, plates, sheets, bars, tubes, wire, and castings, and is employed for tools, mine fittings, screw-machine products, and for various parts requiring a corrosion-resistant and heat-resistant material. The standard grade resists oxidation at temperatures up to 1500° F. Other grades are produced for temperatures up to 2200° F. The melting point is 2723° F. The tensile strength of Ascoloy is 72,000 to 85,000 pounds per square inch.

Delhi Rustless Iron.—Delhi Rustless Iron is the trade name of a chromium-silicon alloy iron having high rust-resisting and acid-resisting properties. It is also claimed to withstand continuous heating up to 1600° F. without scaling. It is a product of the Ludlum Steel Company, Watervliet, N. Y. It belongs to the class of stainless irons and steels, but its low carbon content does not permit hardening. It can be forged readily, and is used for machine parts and for articles where oxidation resistance is important. Delhi rustless iron contains, in a typical analysis, about 18 per cent of chromium, 1.5 of silicon, and not more than 0.08 per cent of carbon. Various grades are marketed in all standard shapes. The highest grade gives an ultimate strength up to 110,000 pounds per square inch when rolled.

Calite.—Calite is the trade name of an iron-nickel alloy of the class known as heat-resistant alloys. It is made in various grades, and resists oxidation when subjected to continuous heating up to 2000° F. A typical Calite contains 35 per cent of nickel, 5 of chromium, 50 of iron, and 10 of aluminum. It has a melting point of 2775° F. Its tensile strength is 56,800 pounds per square inch, and the specific gravity is 7.03. Calite is cast easily, and is used chiefly for boxes for heat-treating purposes. It cannot be machined, nor cut with the gas flame. It is a product of the Calorizing Company, Pittsburgh.

Chromel.—Chromel is the trade name of a nickel-chromium alloy used for heat-resistant castings, and for electrical resistance wires and thermocouples. It is a product of the Hoskins Manufacturing Company, Detroit, Mich. Chromel *A* contains 80 per cent of nickel, and 20 per cent of chromium. Chromel *P* contains 90 per cent of nickel, and 10 of chromium. Chromel *C* has 64 per cent of nickel, 11 of chromium, and 25 of iron. The tensile strength of Grade *A* is about 120,000 pounds per square inch, and the melting point is 1420° C. The melting point of Grade *C* is 1390° C., and that of Grade *P* is 1435° C.

Fahralloy.—Fahralloy is the trade name of a heat-resistant and corrosion-resistant alloy used for making annealing and carbonizing boxes, and for chemical machinery parts. It is made in thirteen grades, containing different percentages of chromium and nickel, and will withstand continuous temperatures up to 2200° F. without oxidation. Some grades can be machined, and are ductile and malleable, while others are hard and brittle. It is a product of the Southern Manganese Steel Company, St. Louis, Missouri.

Hybnickel.—Hybnickel is the trade name of a group of heat-resistant alloys made by Victor Hybinette, The Pusey and Jones Corporation, Wilmington, Del. Alloy *A* withstands temperatures up to 2100° F., and is used for carburizing boxes, hearth plates, and furnace conveyor parts. Grade *B* is a "high-rigidity" alloy for temperatures up to 1800° F. Other grades are *C*, *D*, *R*, and *S*. The latter two are especially made for acid resistance.

Q-Alloys.—Q-Alloys is the trade name of a series of nickel-chromium alloys manufactured by the General Alloys Company, of Chicago. A typical composition is 68 per cent nickel, 20 per cent chromium, and small quantities of silicon, aluminum, and iron. They are of the class of heat-resistant alloys, and a tensile strength of 27,000 pounds per square inch is claimed at a temperature of 1750° F. The alloys are usually cast into boxes for high-temperature work, but the metal is also furnished in sheet form, and in bars, and can be fabricated by welding. Q-alloys will withstand temperatures up to 2200° F. without scaling. They can be cast into intricate shapes. The color is silvery gray.

Rezistal.—Rezistal is a chromium-nickel-silicon "steel" manufactured in several grades, all of which have high percentages of nickel and chromium. It is non-magnetic, and is resistant to heat, chemical action, and corrosion. Its specific gravity is 7.76. It casts very well, making sharp, clear-cut castings. It is rolled and forged at a yellow heat, about 2000° F. When annealed for several hours at 1750° F., and cooled in a furnace, it can be machined readily. It can be forged and welded. In drawn-wire form its tensile strength is as high as 150,000 pounds per square inch. The average tensile strength of the rolled metal is 100,000 pounds per square inch, with elongation of 20 to 35 per cent and Brinell hardness of 225 to 300. All grades of Rezistal are highly resistant to oxidation and scaling up to 2200° F. At 1760° F. the tensile strength is said to be 21,000 pounds per square inch. It is therefore valuable for use in baffle plates, spark-plug electrodes, and other uses where heat resistance or acid resistance is required. It is highly resistant to sea water or mine waters. Rezistal is manufactured under U. S. patents 1,420,707 and 1,420,708 by the Crucible Steel Company of America, New York City.

Silcrome.—Silerome is the trade name of a heat-resistant alloy steel used for automobile-engine valves. It contains high percentages of silicon and chromium, and has a medium carbon content. It is claimed to withstand temperatures up to 1700° F. for long periods without scaling. For internal-combustion engine valve use it does not burn, pit, or warp. It machines readily. Silerome is a product of the Ludlum Steel Company, Watervliet, New York.

SECTION XI

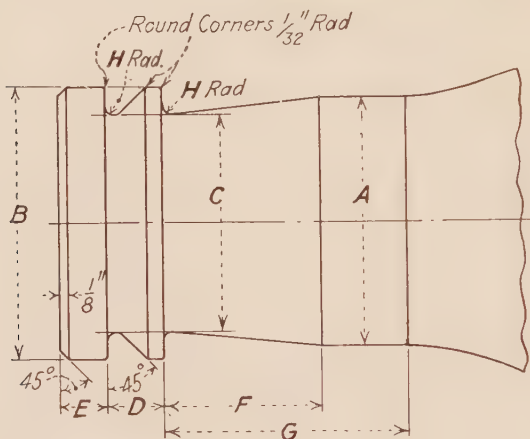
S. A. E. STANDARDS¹

In cooperation with the airplane industry the Society of Automotive Engineers has adopted a number of standards for airplane parts as has been done for the automobile industry, and which has done much to simplify design and reduce manufacturing costs. In addition to the standards given in this section it will be obvious that many of the standards now used in automobile building can also be used in airplane work. It has been thought best, however, to confine the standards for the present at least, to those primarily adopted for airplane work.

With the exception of the proposed standard for adjustable propeller-blade ends and their clamps, all the standards given have been adopted by the S.A.E. as of February, 1929. In view of the increasing use of propellers of this type it has seemed advisable to include these as they seem likely to be adopted in view of the fact that they have been approved by the Army-Navy Standards Conference and are known as AN Standards. The sizes of propeller-blade ends when made of aluminum alloy and of the clamp rings and bolts are given after the standards for taper and splined hubs. The other standards follow:

¹ From the report of the Aeronautic Division, adopted by the Society, February 1929.

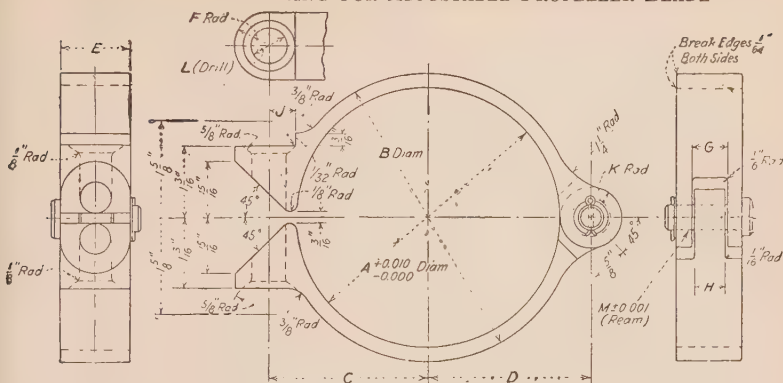
PROPELLER-HUBS AND SHAFT-ENDS

STANDARD END FOR ADJUSTABLE ALUMINUM ALLOY PROPELLER BLADE
END

Material—Aluminum Alloy

Blade End Number (Hp. Recommended)	A	B	C	D	E	F	G	H
00	2.250 ^{+0.000} _{-0.003}	2.495 ^{+0.000} _{-0.003}	2.000 ^{+0.010} _{-0.000}	0.500 ^{+0.002} _{-0.000}	0.4375 ^{+0.010} _{-0.000}	1.3125 ^{+0.010} _{-0.000}	2.1875 ^{+1/16} _{-0.000}	3/32
0	3.000 ^{+0.000} _{-0.003}	3.250 ^{+0.000} _{-0.003}	2.625 ^{+0.010} _{-0.000}	0.6875 ^{+0.002} _{-0.000}	0.562 ^{+0.010} _{-0.000}	1.6875 ^{+0.010} _{-0.000}	2.9375 ^{+1/16} _{-0.000}	1/8
1	3.875 ^{+0.000} _{-0.003}	4.245 ^{+0.000} _{-0.003}	3.375 ^{+0.010} _{-0.000}	0.875 ^{+0.002} _{-0.000}	0.750 ^{+0.010} _{-0.000}	2.375 ^{+0.010} _{-0.000}	3.750 ^{+1/16} _{-0.000}	5/32
1/2	4.1875 ^{+0.000} _{-0.003}	4.620 ^{+0.000} _{-0.003}	3.6875 ^{+0.010} _{-0.000}	1.0625 ^{+0.002} _{-0.000}	0.875 ^{+0.010} _{-0.000}	2.6875 ^{+0.010} _{-0.000}	4.1875 ^{+1/16} _{-0.000}	5/32
2	4.500 ^{+0.000} _{-0.003}	4.995 ^{+0.000} _{-0.003}	3.875 ^{+0.010} _{-0.000}	1.250 ^{+0.002} _{-0.000}	1.000 ^{+0.010} _{-0.000}	3.125 ^{+0.010} _{-0.000}	4.625 ^{+1/16} _{-0.000}	5/32
3	5.000 ^{+0.000} _{-0.003}	5.620 ^{+0.000} _{-0.003}	4.3125 ^{+0.010} _{-0.000}	1.375 ^{+0.002} _{-0.000}	1.125 ^{+0.010} _{-0.000}	3.438 ^{+0.010} _{-0.000}	5.124 ^{+1/16} _{-0.000}	3/16

STANDARD CLAMP RING FOR ADJUSTABLE PROPELLER BLADE



Material - Steel - 2330, 6130 or 6135

Finish - Cadmium Plate

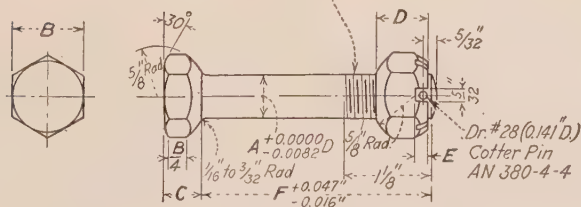
Heat Treat - Tensile Strength 125,000 lb per sq. in.

Scleroscope Hardness 35-40

Size	A	B	C	D	E	F	G	H	J	K	L	M
4 1/4	4 1/16	2 3/16	2 5/8	1 1/8	9/16	9/16	17/32	7/16	1/2	19/32	0.438	
4 3/8	4 3/16	2 3/8	2 1/2	1 1/8	9/16	9/16	17/32	7/16	1/2	19/32	0.438	
4 7/8	5 1/16	2 3/4	2 1/8	1 3/8	13/16	13/16	19/32	9/16	15/32	3/16	21/32	0.500
5	5 1/2	3	3 1/16	1 1/4	5/8	5/8	19/32	15/32	9/16	21/32	0.500	

STANDARD BOLTS FOR ADJUSTABLE PROPELLER CLAMP RING

18 Threads per Inch - U.S. Form

 $G + 0.0000$
 $- 0.0030$ D. (Pitch Dia. After Plating)

Bolts - Steel 2330, 6130 or 6135

Nuts - Steel - 1025

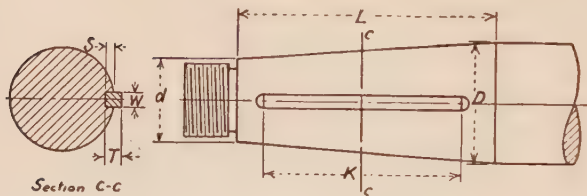
Scleroscope Hardness for Bolts 35-40

Heat Treat Bolts - Tensile Strength 125,000 lb per sq. in.

Finish - Cadmium Plate

Size	A	B	C	D	E	F	G	Clamp Ring
9/16 - 18	0.5625	7/8	15/32	21/32	3/16	2 7/8	0.5264	4 1/4 - 4 3/8
5/8 - 18	0.6250	15/16	33/64	49/64	1/4	3	0.5889	4 5/8 - 5

TAPER SHAFTS



Shaft No.	L, length	In-cluded angle ¹	d, diam-eter at small end	D, diam-eter at large end	Key			
					K, length	W, width	T, thickness	S
1	5½/32	5°43'30" 1.2 in. per ft.	1.535	2.05	3	0.375+0.0000 -0.0005	0.2775±0.0005	0.156±0.002
2	7	5°43'30" 1.2 in. per ft.	1.662	2.362	5⅞/16	0.473±0.001	0.236+0.001 -0.002	0.148±0.005

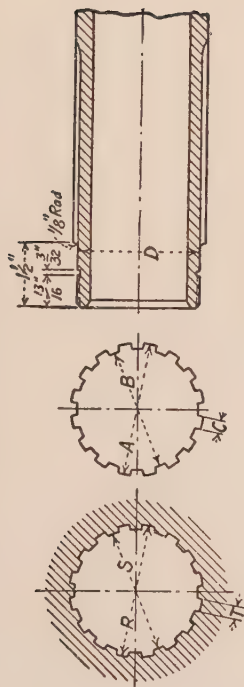
¹ The taper should vary from absolute uniformity by being from 0.000 to 0.001 in. larger at the large end

THREADS

General Information

Threads generally used on the No. 1 taper shaft-end is 1½-18 (external) American Standard (NF), or 1⅝-24 (internal) American Standard (NF). The thread in general use on the No. 2 taper shaft-end is 1⅞-12 (external) American Standard (NF). Note. NF indicates National Fine pitch.

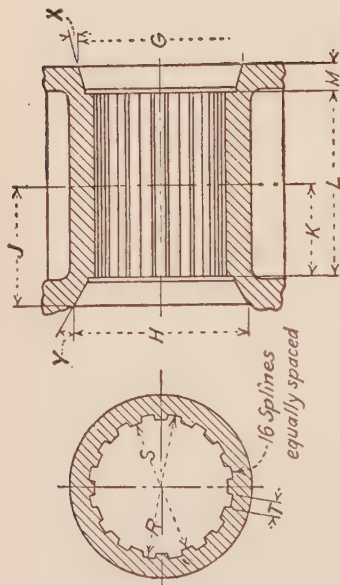
SPLINED SHAFTS



	Shaft-ends				Hub			
	A	B	C	Thread	D	R	S	T
Shaft No. 10	2.000+0.000 -0.002	1.781 max.	0.194 ± 0.0008	1 1/16-12 U. S. F.	1.687+0.000 -0.002	2.008+0.005 -0.002	1.789+0.005 -0.002	0.1960 ± 0.001
Shaft No. 20	2.375+0.000 -0.002	2.156 max.	0.231 ± 0.0008	2 1/16-12 U. S. F.	2.062+0.000 -0.002	2.383+0.005 -0.002	2.164+0.005 -0.002	0.2330 ± 0.001
Shaft No. 30	2.625+0.000 -0.002	2.406 max.	0.257 ± 0.0008	2 3/16-12 U. S. F.	2.312+0.000 -0.002	2.633+0.005 -0.002	2.414+0.005 -0.002	0.2590 ± 0.001
Shaft No. 40	3.125+0.000 -0.002	2.875 max.	0.304 ± 0.0008	2 3/16-12 U. S. F.	2.812+0.000 -0.002	3.133+0.005 -0.002	2.881+0.005 -0.002	0.3060 ± 0.001

Number of Splines = 16

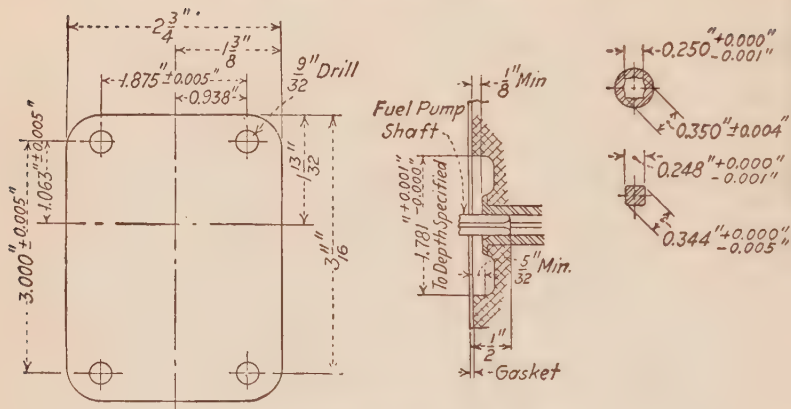
SPLINED HUBS



	Front end		Rear end		J	K	L	M	R	S	T	For rear cone	For front cone
	H	G	X	Y									
Hub No. 10	2.750 + 0.005 - 0.000	2.500 + 0.005 - 0.000	27 3/32	1 5/8	3 1/4	5/8	2.008 + 0.005 - 0.002	1.789 + 0.005 - 0.002	0.1960 + 0.001	15°	30°		
Hub No. 20	3.125 + 0.005 - 0.000	2.875 + 0.005 - 0.000	2 5/8	2	4	5/8	2.383 + 0.005 - 0.002	2.164 + 0.005 - 0.002	0.2330 + 0.001	15°	30°		
Hub No. 30	3.187 + 0.005 - 0.000	3.187 + 0.005 - 0.000	22 5/32	2 3/16	4 3/8	5/8	2.633 + 0.005 - 0.002	2.414 + 0.005 - 0.002	0.2590 + 0.001	15°	30°		
Hub No. 40	3.875 + 0.005 - 0.000	3.625 + 0.005 - 0.000	2 5/8	2	4	5/8	3.133 + 0.005 - 0.002	2.881 + 0.005 - 0.002	0.3060 + 0.001	15°	30°		

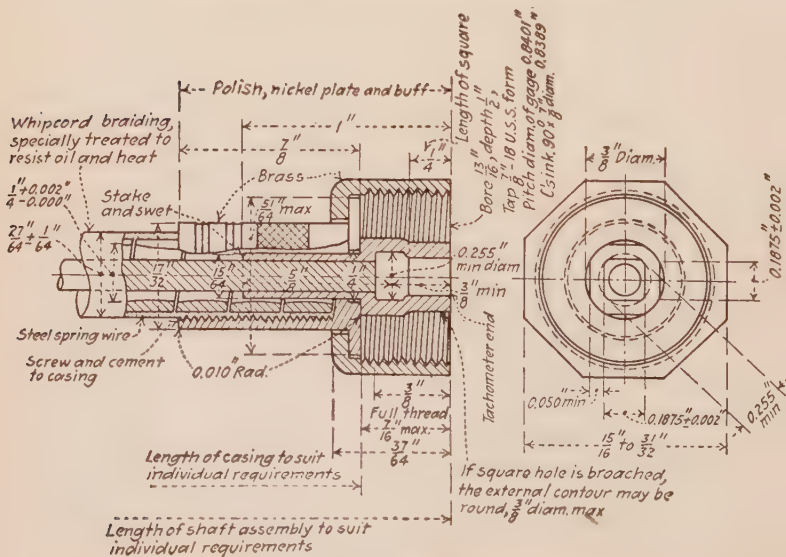
FUEL-PUMP MOUNTING

FUEL PUMP MOUNTING DIMENSIONS

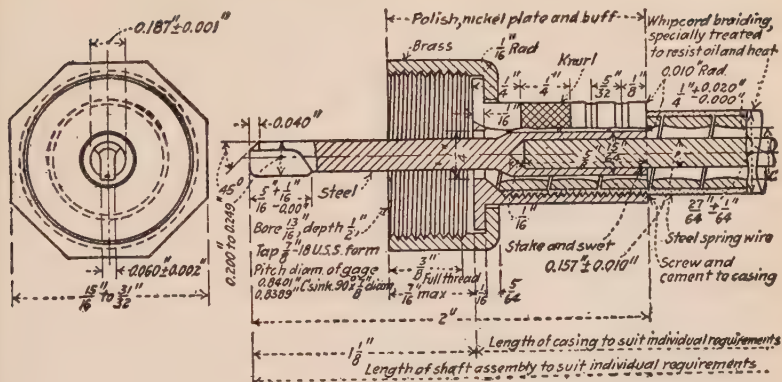


TACHOMETER DRIVE

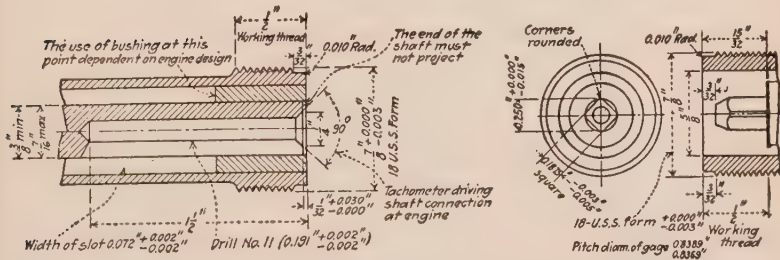
INSTRUMENT END OF TACHOMETER DRIVE



ENGINE END OF TACHOMETER DRIVE SHAFT



ENGINE AND TACHOMETER SHAFT CONNECTIONS



Instrument End.—The upper or instrument end of the shaft has a squared socket, made integral with a shoulder which forms a thrust bearing.

Engine End.—The lower or engine end is finished with a cylindrical end with a single integral key.

Casing.—The casing shall be of flexible metallic tubing covered with whipcord braid and impregnated to prevent oil leakage; similar to sample, or covered with other material which will be equally flexible, oil-tight and free from stretching and of no greater weight than the whipcord braid cover-

ing casing. The outside diameter of casing over braid to be approximately $\frac{7}{16}$ inch; the inside diameter of casing to be approximately $\frac{1}{4}$ inch. The ends of the casing are finished alike, as shown in detailed sketches. The screw-threaded sockets covering the whipcord braid are screwed in place and set with shellac or other suitable material to form an oil-tight and permanent connection.

Shaft-end.—The shaft-end at the engine is drilled and slotted to fit the tachometer shaft-end, allowing for end-play of at least 1 inch. More play than this may be required where the drive shaft is more than 6 foot in length, the amount to be determined experimentally.

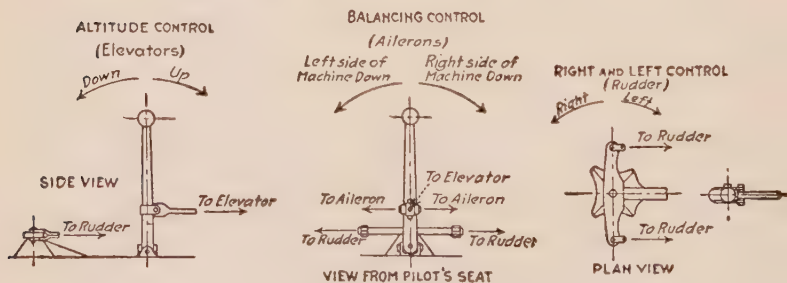
Drive Shaft.—The drive shaft shall be of helical wire wound construction, with core wires.

Spindle.—The tachometer spindle is finished square to fit the square socket on the drive shaft.

Drive Shaft.—The drive shaft shall rotate at one-half crankshaft speed.

End Nuts.—Size and contour of exterior circumference of end nuts is optional, but $1\frac{5}{16}$ inch octagon is recommended.

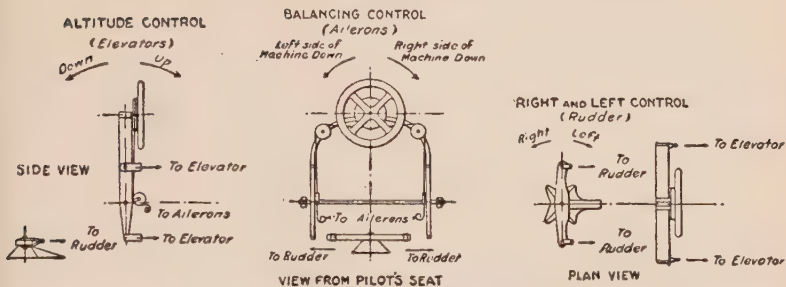
AIRCRAFT STICK CONTROL



The general arrangement and functions of airplane parts for controlling altitude, balance and direction of flight are shown on the following drawing. This recommendation covers the direction of control movements required to produce given results in the line of flight. The stick control is generally used on the lighter and faster types of planes.

AIRPLANE WHEEL CONTROL

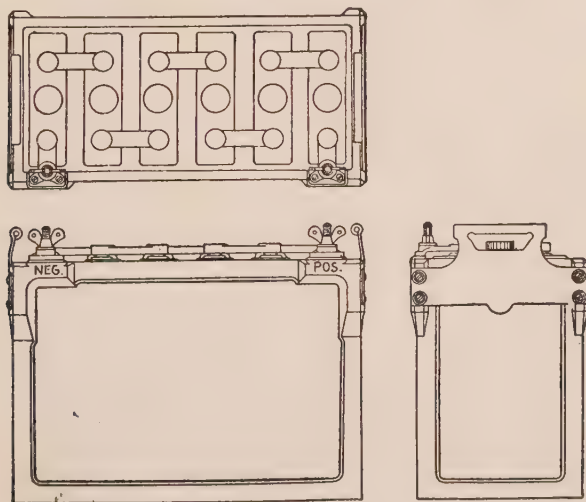
WHEEL CONTROL



The general arrangement and functions of airplane parts for controlling altitude, balance and direction of flight are shown on the following drawing. This recommendation covers the direction of control movements required to produce given results in the line of flight. The wheel control, sometimes called "bridge control," is generally used for the heavier and slower types of planes.

AIRCRAFT STORAGE-BATTERIES

These specifications are intended to apply only to lead-acid storage-batteries for aircraft.



Ratings.—The 5-hour rating of batteries for combined starting and lighting service shall indicate the lighting ability and shall be the capacity in ampere-hours of the battery when it is discharged continuously at the 5-hour rate to a final voltage of not less than 1.75 per cell, the temperature of the battery at the beginning of such discharge being 80° F. The second rating shall indicate the starting ability and shall be the minimum current in amperes that the battery will deliver when discharged continuously at the 20-minute rating to a final voltage of not less than 1.5 per cell, the temperature of the battery at the beginning of such discharge being 80° F.

Non-spillable Feature.—Means shall be provided to prevent the escape of electrolyte when the battery is turned in an inverted position, or in any position between normal and the inverted position, and allowed to remain in any position for an indefinite period. During this test the electrolyte shall be adjusted to normal level.

Terminals.—Aircraft storage-batteries shall be equipped with wing-nut terminals secured to the top of the battery box in such a manner that vibrations from the external leads will be absorbed by the battery box and not transmitted to the terminal posts. Both terminals shall be located on the same side of the battery, with the positive to the right when looking at the terminal side of the battery.

Terminals shall have a $\frac{5}{16}$ -13 American Standard thread, with tolerances providing a Class 2 fit.

Battery terminals and cable terminals shall be lead-coated.

Battery No.	Number of cells	Minimum capacity at 5-hour rate, ampere hour	Minimum current for 20 min., amp. (see note)	Maximum over-all dimensions, inch			Maximum weight wet, pound
				Length ¹	Width	Height	
32	6 ^a	29½	50	8½ ₁₆	7¼	11¼	38
34	6 ^a	43	75	11½	7¼	11¼	53
36	6 ^a	65	113	14½	7¼	11¼	70

¹ The over-all end-to-end length includes handles, not hold-down devices. The handles and the hold-down devices shall be attached only to the ends of the case.

^a Side-to-side assembly of cells.

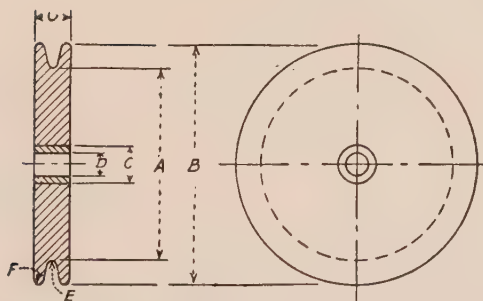
From the report of the Aeronautic Division, adopted by the Society, August 1928.

NOTE

The Standards Committee will be asked to take action on a Sub-committee recommendation to change the 20-minute rating for aircraft storage batteries to read as follows:

Battery No.	Minimum current for 20 minutes, amperes
32	44
34	66
36	99

PULLEYS NON-METALIC



No.	Cable size	A	B	C	D +0.002 -0.002	E radius	F	G +0.015 -0.015
1	$\frac{1}{16}$ - $\frac{3}{32}$	$\frac{7}{8}$	$1\frac{1}{4}$	$\frac{3}{8}$	0.253	$\frac{3}{64}$	$\frac{1}{32}$	$1\frac{7}{64}$
2	$\frac{1}{16}$ - $\frac{3}{32}$	2	$2\frac{1}{2}$	$\frac{3}{8}$	0.253	$\frac{3}{64}$	$\frac{1}{32}$	$1\frac{7}{64}$
3	$\frac{1}{8}$ - $\frac{5}{32}$ - $\frac{3}{16}$	$1\frac{3}{8}$	2	$\frac{1}{2}$	0.378	$\frac{7}{64}$	$\frac{3}{64}$	$\frac{7}{16}$
4	$\frac{1}{8}$ - $\frac{5}{32}$ - $\frac{3}{16}$	$2\frac{7}{8}$	$3\frac{1}{2}$	$\frac{1}{2}$	0.378	$\frac{7}{64}$	$\frac{3}{64}$	$\frac{7}{16}$

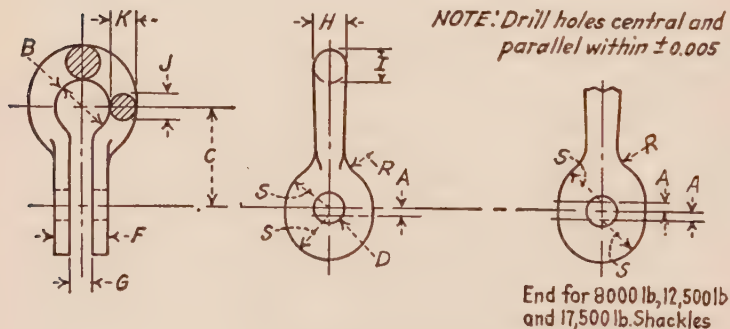
Pulley 1.—To be used for $\frac{1}{16}$ and $\frac{3}{32}$ extra flexible cable where the bend is 30 deg. or less.

Pulley 2.—To be used for $\frac{1}{16}$ and $\frac{3}{32}$ extra flexible cable where the bend is greater than 30 deg.

Pulley 3.—To be used for $\frac{1}{8}$, $\frac{5}{32}$ and $\frac{3}{16}$ extra flexible cable where the bend is 30 deg. or less.

Pulley 4.—To be used for $\frac{1}{8}$, $\frac{5}{32}$ and $\frac{3}{16}$ extra flexible cable where the bend is greater than 30 deg.

SHACKLES



Physical Properties

Shackles shall show the ultimate strength required when subjected to a tensile test. Shackles, when subjected to a bend test made by opening the shackle and bending flat, shall show no signs of cracking.

SHACKLE DIMENSIONS

No. r	Shackle and cable strength, pound	D, +0.010 -0.000	G, +0.010 -0.000	F	S	J	K	H	I	A	B	C	R
8	800	0.188	0.109	0.250	0.250	0.172	0.172	0.172	0.172	0.031	0.250	0.563	0.375
16	1,600	0.188	0.150	0.313	0.250	0.172	0.172	0.172	0.172	0.031	0.250	0.563	0.375
21	2,100	0.188	0.150	0.313	0.281	0.172	0.172	0.172	0.172	0.031	0.250	0.563	0.375
32	3,200	0.250	0.203	0.438	0.313	0.219	0.219	0.250	0.250	0.031	0.375	0.750	0.438
46	4,600	0.313	0.203	0.500	0.375	0.219	0.219	0.281	0.281	0.063	0.438	0.813	0.500
61	6,100	0.375	0.203	0.563	0.375	0.281	0.281	0.313	0.313	0.063	0.500	0.875	0.500
80	8,000	0.375	0.266	0.563	0.406	0.375	0.375	0.438	0.375	0.063	0.438	1.000	0.406
125	12,500	0.438	0.360	0.719	0.531	0.469	0.469	0.594	0.469	0.094	0.625	1.125	0.750
175	17,500	0.500	0.406	0.813	0.625	0.563	0.563	0.688	0.563	0.125	0.625	1.250	0.500

Finished sizes include plating or protective coating.

Tolerances are ± 0.010 except where otherwise indicated.

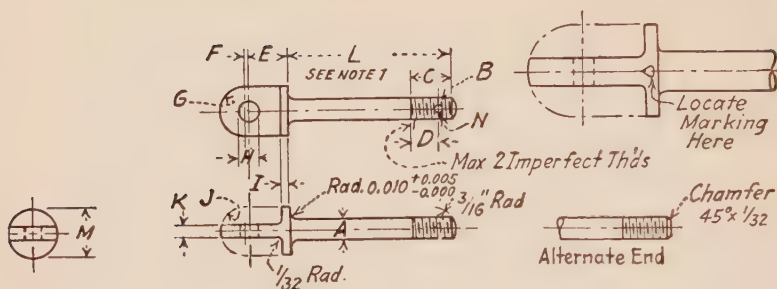
L.H.	3,400	¼-28	1.813	0.250	0.438	0.203	0.625	0.047	0.251	No. 3 (0.2130)	0.375	0.625	0.875	0.438	0.500
R.H.															
L.H.	4,600	5/16-24	1.875	0.313	0.500	0.203	0.656	0.047	0.323	0.2703	0.438	0.688	0.938	0.563	0.625
R.H.															
L.H.	6,100	5/16-24	2.000	0.375	0.563	0.203	0.843	0.063	0.323	0.2703	0.453	0.750	1.000	0.563	0.625
R.H.															
L.H.	8,000	5/8-24	2.250	0.375	0.563	0.266	0.875	0.063	0.386	Q (0.3320)	0.547	0.875	1.125	0.688	0.750
R.H.															
L.H.	11,500	7/16-20	2.500	0.438	0.719	0.344	1.000	0.078	0.453	W (0.3360)	0.625	1.063	1.250	0.750	0.813
R.H.															
L.H.	15,500	1½-20	2.813	0.500	0.818	0.406	1.183	0.078	0.516	0.4492	0.703	1.188	1.438	0.875	0.938
R.H.															
L.H.	20,200	9/16-18	3.125	0.563	0.922	0.453	0.375	0.094	0.578	0.5062	0.796	1.375	1.625	1.000	1.063
R.H.															
L.H.	24,700	5/8-18	3.375	0.625	1.032	0.516	1.500	0.094	0.640	0.5087	0.875	1.500	1.750	1.125	1.188
R.H.															

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

Finished sizes include plating or protective coating.

Tolerances are ± 0.010 , except where otherwise indicated.

EYE-BOLTS



Physical Properties

Assembled bolts shall show required minimum tensile-strength when tested in tension between the head and the nut.

Bolts shall stand cold-bending in the plain part without fracture through an angle of 180 deg. over a diameter equal to the diameter of the bolt. In short bolts the test may be made in threaded part, the angle of bend to be through 35 deg.

Marking

Bolts conforming to these specifications shall be marked in some distinctive manner where shown.

Bolts conforming entirely to Army-Navy material specifications shall be marked with X.

Bolts not marked in either manner will be understood to be made from low-strength material.

EYE-BOLT DIMENSIONS

A ² bolt diameter	Tensile strength, pound (minute)	B ⁴ , thread	C, thread length ²	D	E	F	G, radius	H, +0.010 -0.000	I	J, radius	K, ±0.005	N, drill size	M
0.190 +0.0000 -0.0054	2,190	10-32	3/8	1/4	1 3/32	1/32	7/32	0.188	1/16	7/32	0.094	No. 50 (0.070)	7/16
0.250 +0.0000 -0.0062	4,070	1/4-28	7/16	9/32	1 5/32	1/32	1/4	0.188	5/64	1/4	0.125	No. 48 (0.076)	1/2
0.3125 +0.0000 -0.0066	6,550	5/16-24	7/16	2 1/64	1 7/32	3/64	5/16	0.250	3/32	5/16	0.188	No. 48 (0.076)	5/8
0.3125 +0.0000 -0.0066	6,550	5/16-24	7/16	2 1/64	1 9/32	3/64	1 1/32	0.313	3/32	1 1/32	0.188	No. 48 (0.076)	1 1/16
0.375 +0.0000 -0.0066	10,100	3/8-24	9/16	1 3/32	1 9/32	3/64	3/8	0.375	3/32	3/8	0.188	No. 36 (0.106)	3/4
0.4375 +0.0000 -0.0072	13,620	7/16-20	9/16	2 9/64	2 3/32	1/16	7/16	0.375	1/8	7/16	0.250	No. 36 (0.106)	7/8
0.500 +0.0000 -0.0072	18,580	1/2-20	1 1/16	9/16	1 3/16	1/16	1/2	0.4375	1/8	1/2	0.3125	No. 36 (0.106)	1
0.5625 +0.0000 -0.0082	23,600	9/16-18	3/4	3 9/64	1 5/16	5/64	1 9/32	0.500	1/8	1 9/32	0.375	No. 28 (0.141)	1 3/16

¹ Standard bolt lengths (L) 1/4 to 8 inch by 1/8-inch increments. Tolerances on length, +3/64, -3/64. (See Illustration.)

² Where length of bolt (L) is shorter than C (thread length), bolt is to be threaded entire length.

³ Finished sizes include plating or protective coating.

⁴ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

Tolerances are ±0.010 except where otherwise indicated.

TURNBUCKLES



Assembly No. 1 Cable-Eye and Pin-Eye



Assembly No. 2 Cable-Eye and Cable-Eye



Assembly No. 3 Cable-Eye and Fork

$P = 4\frac{1}{2}$ inch, assembled length—short type

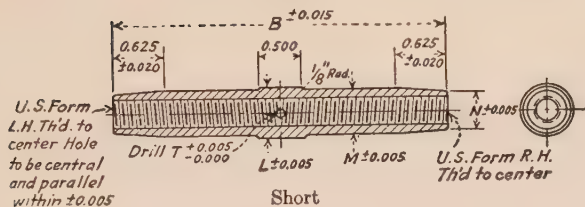
$P = 8$ inch, assembled length—long type

TURNBUCKLE WEIGHTS

(General information)

Short type		Long type	
Strength, pound	Approximate weight, pound	Strength, pound	Approximate weight, pound
800	0.030	1,600	0.094
1,600	0.065	2,100	0.116
2,100	0.084	3,200	0.172
3,200	0.112	4,600	0.250
4,600	0.165	6,100	0.368
		8,000	0.420
		12,500	0.630
		17,500	0.935

BARREL



Strength, pound	Thread ¹	L	M	N	B	T
800	6-40	0.250	0.219	0.188	2.25	0.125
1,600	10-32	0.375	0.281	0.250	2.25	0.125
2,100	12-28	0.375	0.328	0.281	2.25	0.125
3,200	$\frac{1}{4}$ -28	0.438	0.391	0.328	2.25	0.125
4,600	$\frac{5}{16}$ -24	0.500	0.438	0.406	2.25	0.125

Long

1,600	10-32	0.375	0.281	0.250	4.00	0.125
2,100	12-28	0.375	0.328	0.281	4.00	0.125
3,200	$\frac{1}{4}$ -28	0.438	0.391	0.328	4.00	0.125
4,600	$\frac{5}{16}$ -24	0.500	0.438	0.406	4.00	0.125
6,100 8,000	$\frac{3}{8}$ -24	0.625	0.594	0.469	4.00	0.125
12,500	$\frac{7}{16}$ -20	0.750	0.688	0.563	4.25	0.188
17,500	$\frac{1}{2}$ -20	0.875	0.813	0.625	4.25	1.88

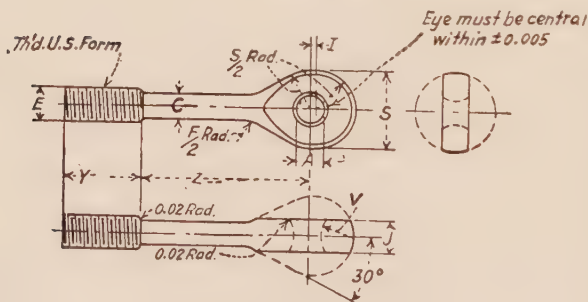
¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch. Tolerances are ± 0.010 except where otherwise indicated.

Physical Properties

Barrels shall be made of rolled brass to provide the following physical properties:

Tensile strength (minimum), pound per square inch	67,000
Yield point (minimum), pound per square inch	45,000
Elongation (minimum) in 2 inch, per cent.	22
Reduction of area (minimum), per cent.	45

CABLE-EYE



Physical Properties

Turnbuckle cable-eyes shall be subjected to a tensile test after plating and shall withstand the test load specified.

The shanks shall be machined preferably from heat-treated cold-drawn or cold-rolled bars. If shanks are not made from heat-treated cold-drawn or cold-rolled bars, they shall be heat-treated after machining to give the physical properties specified.

Turnbuckle shanks meeting the tensile test without breaking shall be held in a square-nose vise and bent through an angle of 90 deg. without failing or cracking.

SHORT CABLE-EYE DIMENSIONS

Hand	Strength, pound	Thread ¹	E	A, +0.010 -0.000	C, +0.006 -0.000	F/2	I, +0.010 -0.000	J	S	V	Y, ±0.047	Z, +0.031 -0.015
L. H.	800	6-40	0.138 +0.0000 -0.0048	0.188	0.094	0.125	0.031	0.125	0.375	0.094	0.375	1.125
R. H.												
L. H.	1,600	10-32	0.190 +0.0000 -0.0054	0.219	0.133	0.156	0.031	0.188	0.500	0.172	0.500	1.125
R. H.												
L. H.	2,100	12-28	0.216 +0.0000 -0.0062	0.219	0.155	0.156	0.031	0.188	0.500	0.172	0.563	1.125
R. H.												
L. H.	3,200	3/4-28	0.250 +0.0000 -0.0062	0.281	0.189	0.219	0.047	0.219	0.625	0.203	0.625	1.125
R. H.												
L. H.	4,600	5/16-24	0.3125 +0.0000 -0.0066	0.313	0.243	0.250	0.047	0.281	0.688	0.250	0.750	1.125
R. H.												

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

Finished sizes include plating or protective coating.

Tolerances are ±0.010 except where otherwise indicated.

LONG CABLE-EYE DIMENSIONS

Hand	Strength, pound	Thread ¹	<i>F</i>	<i>A</i> , +0.010 -0.000	<i>C</i> , +0.006 -0.000	<i>F</i> /2	<i>I</i> , +0.010 -0.000	<i>J</i>	<i>S</i>	<i>V</i>	<i>Y</i> , ±0.047	<i>Z</i> , +0.031 -0.015
L. H. — R. H.	1,600	10 32	0.190 +0.0000 -0.0054	0.219	0.133	0.156	0.031	0.188	0.500	0.172	0.500	2.000
L. H. — R. H.	2,100	12 28	0.216 +0.0000 -0.0062	0.219	0.155	0.156	0.031	0.188	0.500	0.172	0.563	2.000
L. H. — R. H.	3,200	3/4 28	0.250 +0.0000 -0.0062	0.281	0.189	0.219	0.047	0.219	0.625	0.203	0.625	2.000
L. H. — R. H.	4,600	5/16-24	0.3125 +0.0000 -0.0066	0.313	0.243	0.250	0.047	0.281	0.688	0.250	0.750	2.000
L. H. — R. H.	6,100	3/8 24	0.375 +0.0000 -0.0066	0.344	0.256	0.281	0.063	0.281	0.750	0.313	0.875	2.000
L. H. — R. H.	8,000	3/8-24	0.375 +0.0000 -0.0066	0.375	0.306	0.281	0.063	0.328	0.875	0.375	0.875	2.000

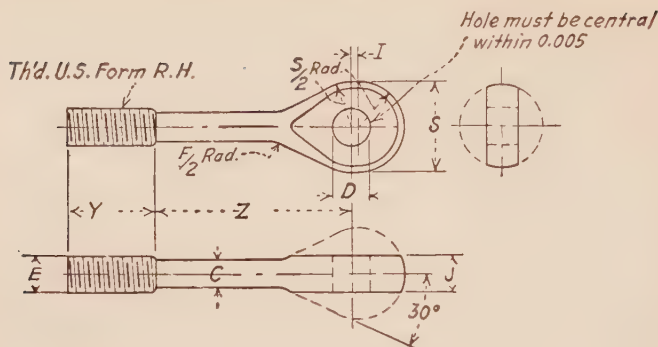
L. H.	12.500	$\frac{7}{16}$ -20	0.4375 +0.0000 -0.0072	0.469	0.362	0.359	0.078	0.375	1.063	0.453	1.000	2.375
R. H.												
L. H.	17.500	$1\frac{1}{2}$ 20	0.500 +0.0000 -0.0072	0.563	0.425	0.406	0.078	0.469	1.188	0.500	1.000	2.625
R. H.												

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

Finished sizes include plating or protective coating.

Tolerances are ± 0.010 except where otherwise indicated.

PIN-EYE



Physical Properties

Turnbuckle pin-eyes shall be subjected to a tensile test after plating and shall withstand the test load specified.

The pin-eye shall be machined preferably from heat-treated cold-drawn or cold-rolled bars. If pin-eyes are not made from heat-treated cold-drawn or cold-rolled bars, they shall be heat-treated after machining to give physical properties specified.

Turnbuckle pin-eyes meeting the tensile test without breaking shall be held in a square-nose vise and bent through an angle of 90 deg. without failing or cracking.

SHORT PIN-EYE DIMENSIONS

Strength, pound	Thread ¹	<i>E</i>	<i>D</i> , +0.010 -0.000	<i>C</i> , +0.006 -0.000	<i>F</i> /2	<i>I</i> , +0.010 -0.000	<i>J</i>	<i>S</i>	<i>Y</i> , ±0.047	<i>Z</i> , +0.031 -0.015
800	6-40	0.1218+0.0000 -0.0017	0.188	0.094	0.125	0.031	0.125	0.375	0.375	1.125
1,600	10-32	0.1697+0.0000 -0.0019	0.188	0.133	0.156	0.031	0.188	0.500	0.500	1.125
2,100	12-28	0.1928+0.0000 -0.0022	0.188	0.155	0.156	0.031	0.188	0.500	0.563	1.125
3,200	¼-28	0.2268+0.0000 -0.0022	0.250	0.189	0.219	0.047	0.219	0.625	0.625	1.125
4,600	5/16-24	0.2854+0.0000 -0.0024	0.313	0.243	0.250	0.047	0.281	0.688	0.750	1.125

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

Finished sizes include plating or protective coating.

Tolerances are ±0.010 except where otherwise indicated.

LONG PIN-EYE DIMENSIONS

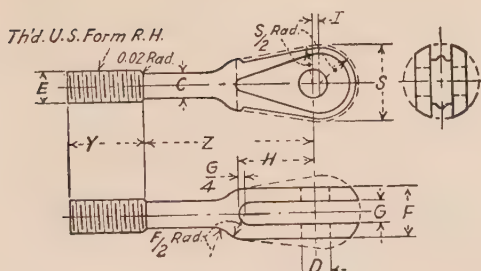
Strength, pound	Thread ¹	Pitch diameter	D , +0.010 -0.000	C , +0.006 -0.000	$F/2$	I , +0.010 -0.000	J	S	Y , ± 0.047	Z , +0.031 -0.015
1,600	10-32	0.1697+0.0000 -0.0019	0.188	0.133	0.156	0.031	0.188	0.500	0.500	2.000
2,100	12-28	0.1928+0.0000 -0.0022	0.188	0.155	0.156	0.031	0.188	0.500	0.563	2.000
3,200	$\frac{1}{4}$ -28	0.2260+0.0000 -0.0022	0.250	0.189	0.219	0.047	0.219	0.625	0.625	2.000
4,600	$\frac{5}{16}$ -24	0.2854+0.0000 -0.0024	0.313	0.243	0.250	0.047	0.281	0.688	0.750	2.000
6,100	$\frac{3}{8}$ -24	0.3479+0.0000 -0.0024	0.375	0.256	0.281	0.063	0.281	0.750	0.875	2.000
8,000	$\frac{3}{8}$ 24	0.3479+0.0000 -0.0024	0.375	0.306	0.281	0.063	0.328	0.875	0.875	2.000
12,500	$\frac{7}{16}$ -20	0.4050+0.0000 -0.0026	0.438	0.362	0.359	0.078	0.375	1.063	1.000	2.375
17,500	$\frac{1}{2}$ -20	0.4675+0.0000 -0.0026	0.500	0.425	0.406	0.078	0.469	1.188	1.000	2.625

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

Finished sizes include plating or protective coating.

Tolerances are ± 0.010 except where otherwise indicated.

FORK



Physical Properties

Turnbuckle forks shall be subjected to a tensile test after plating and shall withstand the test load specified.

The forks shall be machined preferably from heat-treated cold-drawn or cold-rolled bars. If forks are not made from heat-treated cold-drawn or cold-rolled bars, they shall be heat-treated after machining to give the physical properties specified.

Turnbuckle forks meeting the tensile test without breaking shall be held in a square-nose vise, and bent through an angle of 90 deg. without failing or cracking.

SHORT FORK DIMENSIONS

Strength, pound	Thread ¹	E	C, +0.006 -0.000	D, +0.010 -0.000	F, +0.010 -0.005	G, +0.010 -0.000	H	I, +0.010 -0.000	S	Y, ±0.047	Z, +0.031 -0.015
800	6-40	0.138 +0.0000 -0.0048	0.094	0.188	0.250	0.109	0.375	0.031	0.375	0.375	1.125
1,600	10-32	0.190 +0.0000 -0.0054	0.133	0.188	0.313	0.150	0.469	0.031	0.500	0.500	1.125
2,100	12-28	0.216 +0.0000 -0.0062	0.155	0.188	0.313	0.150	0.562	0.031	0.500	0.563	1.125
3,200	¼-28	0.250 +0.0000 -0.0062	0.189	0.250	0.438	0.203	0.625	0.047	0.625	0.625	1.125
4,600	⅞-24	0.3125 +0.0000 -0.0066	0.243	0.313	0.500	0.203	0.656	0.047	0.688	0.750	1.125

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.
 Finished sizes include plating or protective coating.

Tolerances are ±0.010 except where otherwise indicated.

LONG FORK DIMENSIONS

Strength, pound	Thread ¹	E	C, +0.006 -0.000	D, +0.010 -0.000	F, +0.010 -0.005	G, +0.010 -0.000	H	I, +0.010 -0.000	S	Y, ±0.047	Z, +0.031 -0.015
1,600	10-32	0.190 +0.0000 -0.0054	0.133	0.188	0.313	0.150	0.469	0.031	0.500	0.500	2.000
2,100	12-28	0.216 +0.0000 -0.0062	0.155	0.188	0.313	0.150	0.562	0.031	0.500	0.563	2.000
3,200	1/4-28	0.250 +0.0000 -0.0062	0.189	0.250	0.438	0.203	0.625	0.047	0.625	0.625	2.000
4,600	5/16-24	0.3125+0.0000 -0.0066	0.243	0.313	0.500	0.203	0.656	0.047	0.688	0.750	2.000
6,100	3/8-24	0.375 +0.0000 -0.0066	0.256	0.375	0.563	0.203	0.843	0.063	0.750	0.875	2.000
8,000	3/8-24	0.375 +0.0000 -0.0066	0.306	0.375	0.563	0.266	0.875	0.063	0.875	0.875	2.000
12,500	7/16-20	0.4375+0.0000 -0.0072	0.362	0.438	0.719	0.344	1.000	0.078	1.063	1.000	2.375
17,500	1/2-20	0.500 +0.0000 -0.0072	0.425	0.500	0.813	0.406	1.188	0.078	1.188	1.000	2.625

¹ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine pitch.

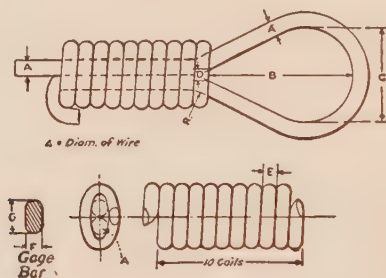
Finished sizes include plating or protective coating.

Tolerances are ±0.010 except where otherwise indicated.

WIRE LOOPS AND FERRULES

AERONAUTIC

The loops for round tinned steel wire are made by threading the tension wire through a ferrule, forming a loop of the specified size, slipping the ferrule up against the loop and bending the free end of the tension wire over the ferrule as shown. The ferrule is then thoroughly soldered in place without drawing the temper of the tension wire.

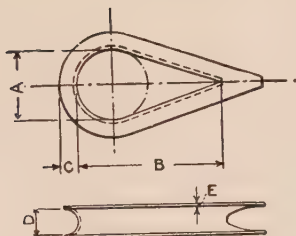


Round wire loops					Ferrule E		Gage bar		
Size of wire, (A)		B	C	D	R	B. & S. gage	Inch	F	G
B. & S. gage	Inch								
8	0.128	$\frac{9}{16}$	$2\frac{3}{64}$	$\frac{5}{64}$	$1\frac{3}{64}$	9	0.114	0.130	0.260
8	0.128	$\frac{7}{16}$	$1\frac{7}{64}$	$\frac{1}{16}$	$\frac{9}{64}$	9	0.114	0.130	0.260
10	0.102	$1\frac{5}{32}$	$\frac{9}{32}$	$\frac{1}{32}$	$\frac{9}{64}$	11	0.091	0.104	0.208
12	0.081	$1\frac{3}{32}$	$1\frac{7}{64}$	$\frac{1}{32}$	$\frac{9}{64}$	13	0.072	0.083	0.166
14	0.064	$1\frac{3}{32}$	$1\frac{7}{64}$	$\frac{1}{32}$	$\frac{9}{64}$	15	0.057	0.066	0.132

Dimensions given in inches. Dimensions "A" and "E" are minima—tolerance, plus 0.002 inch. The gage bar has semicircular edges and shall pass through the ferrule with a clearance of approximately 0.003 inch.

STEEL THIMBLES

AERONAUTIC



Diameter of cable		A	B	C	D	E	Approx. weight, pound per 1,000 pieces
Nominal	Decimal						
$\frac{1}{16}$	0.062	0.35	0.70	0.07	0.09	0.032	3.00
$\frac{3}{32}$	0.094	0.35	0.70	0.07	0.09	0.032	3.00
$\frac{1}{8}$	0.125	0.35	0.70	0.07	0.13	0.032	4.34
$\frac{5}{32}$	0.156	0.40	0.80	0.10	0.17	0.032	6.36
$\frac{3}{16}$	0.187	0.50	1.00	0.135	0.21	0.032	9.00
$\frac{7}{32}$	0.219	0.60	1.20	0.15	0.24	0.032	13.50
$\frac{1}{4}$	0.250	0.70	1.40	0.17	0.25	0.032	16.63
$\frac{9}{32}$	0.281	0.80	1.60	0.198	0.30	0.040	30.36
$\frac{5}{16}$	0.312	0.90	1.80	0.21	0.33	0.040	33.00
$\frac{3}{8}$	0.375	1.00	2.00	0.26	0.39	0.060	74.00

Dimensions in inches.

The thimbles shall be galvanized by either the electrical or hot-dip process.

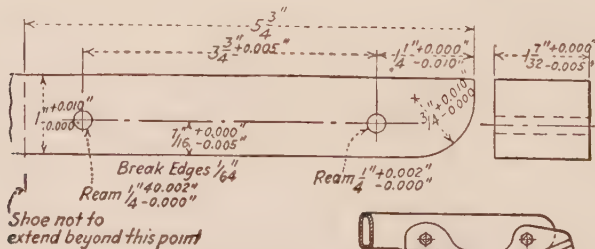
FLAT WASHERS



Nominal bolt size	H	Large		Small	
		D	T	D	T
No. 8	$1\frac{1}{64}$	....	...	$\frac{5}{16}$	$\frac{1}{32}$
No. 10	$1\frac{3}{64}$	$\frac{7}{8}$	$\frac{1}{16}$	$\frac{3}{8}$	$\frac{1}{32}$
$\frac{1}{4}$	$1\frac{7}{64}$	$1\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{2}$	$\frac{1}{16}$
$\frac{5}{16}$	$2\frac{1}{64}$	$1\frac{3}{8}$	$\frac{1}{16}$	$\frac{9}{16}$	$\frac{1}{16}$
$\frac{3}{8}$	$2\frac{5}{64}$	$1\frac{5}{8}$	$\frac{1}{16}$	$1\frac{1}{16}$	$\frac{1}{16}$
$\frac{7}{16}$	$2\frac{9}{64}$	$1\frac{13}{16}$	$\frac{1}{10}$	$1\frac{3}{16}$	$\frac{1}{16}$
$\frac{1}{2}$	$3\frac{3}{64}$	2	$\frac{1}{10}$	$1\frac{5}{16}$	$\frac{1}{16}$
$\frac{9}{16}$	$3\frac{7}{64}$	$2\frac{3}{16}$	$\frac{1}{8}$	$1\frac{1}{16}$	$\frac{1}{16}$
$\frac{5}{8}$	$4\frac{1}{64}$	$2\frac{3}{8}$	$\frac{1}{8}$	$1\frac{1}{8}$	$\frac{1}{16}$

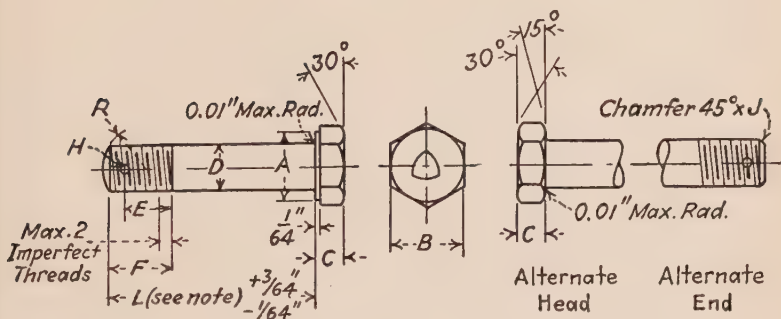
TAIL-SKID SHOE MOUNTINGS

Tail-skid Shoes for airplanes under 4,500-pound weight shall fit a jig having the dimensions as shown.



PLAIN HEXAGON-HEAD BOLTS

AERONAUTIC



Physical Properties

Assembled bolts shall show required minimum tensile-strength when tested in tension between the head and the nut.

Bolts shall stand cold-bending in the plain part without fracture through an angle of 180 deg. over a diameter equal to the diameter of the bolt. In short bolts the test may be made in threaded part, the angle of the bend to be through 35 deg.

Marking

Bolts conforming to these specifications shall be marked in some distinctive manner where shown.

Bolts conforming entirely to Army-Navy material specifications shall be marked with X.

Bolts not marked in either manner will be understood to be made from low-strength material.

PLAIN HEXAGON-HEAD BOLT DIMENSIONS

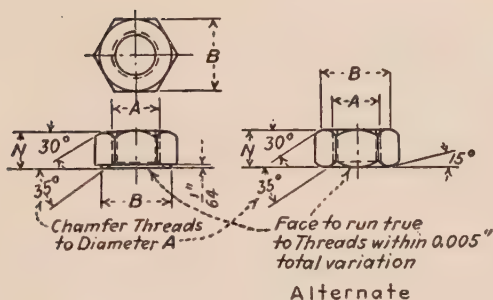
Nominal bolt size	Threads per inch ¹	A	B	C	D ²	E	F	H	J	R	Tensile strength, minimum, pound
0.1640 (No. 8)	36	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{8}$	0.164 +0.0000 -0.0050	$1\frac{5}{64}$	$\frac{3}{8}$	0.070	$\frac{1}{32}$	$\frac{1}{8}$	.....
0.1900 (No. 10)	32	$\frac{3}{8}$	$\frac{3}{8}$	$\frac{1}{8}$	0.190 +0.0000 -0.0054	$\frac{1}{4}$	$\frac{3}{8}$	0.070	$\frac{1}{32}$	$\frac{3}{16}$	2,190
0.2500 ($\frac{1}{4}$)	28	$\frac{7}{16}$	$\frac{7}{16}$	$\frac{5}{32}$	0.250 +0.0000 -0.0062	$\frac{9}{32}$	$\frac{7}{16}$	0.076	$\frac{1}{32}$	$\frac{1}{4}$	4,070
0.3125 ($\frac{5}{16}$)	24	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{3}{16}$	0.3125 +0.0000 -0.0066	$2\frac{1}{64}$	$\frac{7}{16}$	0.076	$\frac{3}{64}$	$\frac{5}{16}$	6,550
0.3750 ($\frac{3}{8}$)	24	$\frac{9}{16}$	$\frac{9}{16}$	$\frac{7}{32}$	0.375 +0.0000 -0.0066	$1\frac{3}{32}$	$\frac{9}{16}$	0.106	$\frac{3}{64}$	$\frac{3}{8}$	10,100
0.4375 ($\frac{7}{16}$)	20	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{1}{4}$	0.4375 +0.0000 -0.0072	$2\frac{5}{64}$	$\frac{9}{16}$	0.109	$\frac{3}{64}$	$\frac{7}{16}$	13,620
0.5000 ($\frac{1}{2}$)	20	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{9}{32}$	0.500 +0.0000 -0.0072	$\frac{9}{16}$	$1\frac{1}{16}$	0.106	$\frac{3}{64}$	$\frac{1}{2}$	18,580
0.5625 ($\frac{9}{16}$)	18	$\frac{7}{8}$	$\frac{7}{8}$	$\frac{5}{16}$	0.5625 +0.0000 -0.0082	$\frac{3}{8}$	$\frac{3}{4}$	0.141	$\frac{3}{64}$	$\frac{9}{16}$	23,600
0.6250 ($\frac{5}{8}$)	18	$1\frac{1}{16}$	$1\frac{1}{16}$	$1\frac{1}{32}$	0.625 +0.0000 -0.0082	$1\frac{1}{16}$	$1\frac{1}{16}$	0.141	$\frac{3}{64}$	$\frac{5}{8}$	30,000

Bolt lengths $\frac{1}{4}$ to 8 inch by $\frac{1}{8}$ -inch increments. Where L is shorter than F , bolt is to be threaded entire length. NF = National Fine pitch.

¹ Threads are American Standard (NF), with Class 3 tolerances. ² Finished sizes include plating or treatment.

PLAIN HEXAGONAL NUTS

AERONAUTIC



Nominal size, A ²	Threads per inch ³	B, width across flats	N ¹	
			Full-strength nuts, ±0.005	Thin and check nuts ±0.005
0.1640 (No. 8)	36	$\frac{3}{8}$	$\frac{1}{8}$	$\frac{1}{8}$
0.1900 (No. 10)	32	$\frac{3}{8}$	$\frac{9}{64}$	$\frac{9}{64}$
0.2500- $\frac{1}{4}$	28	$\frac{7}{16}$	$\frac{3}{16}$	$\frac{1}{8}$
0.3125- $\frac{5}{16}$	24	$\frac{1}{2}$	$1\frac{5}{64}$	$\frac{5}{32}$
0.3750- $\frac{3}{8}$	24	$\frac{9}{16}$	$\frac{9}{32}$	$\frac{3}{16}$
0.4375- $\frac{7}{16}$	20	$\frac{5}{8}$	$2\frac{1}{64}$	$\frac{7}{32}$
0.5000- $\frac{1}{2}$	20	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{4}$
0.5625- $\frac{9}{16}$	18	$\frac{7}{8}$	$2\frac{7}{64}$	$\frac{9}{32}$
0.6250- $\frac{5}{8}$	18	$1\frac{5}{16}$	$1\frac{5}{32}$	$\frac{5}{16}$

¹ For full-strength nuts $N = 3A/4$. For check nuts and thin nuts for shear bolts $\frac{1}{4}$ in. diameter and larger $N = A/2$.

² Finished sizes include plating or protective coating.

³ Threads are American Standard (NF), with Class 3 tolerances. NF indicates National Fine Pitch.

Tolerances are ±0.010 except where otherwise indicated.

Physical Properties

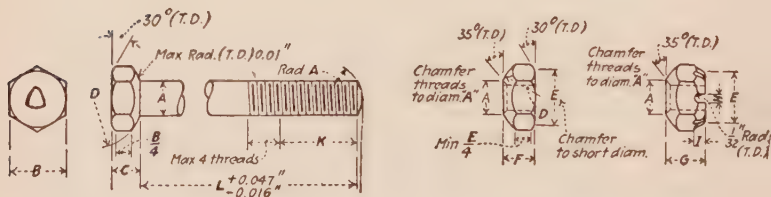
Nuts shall be manufactured from bar steel having the following physical properties:

Tensile strength (minimum), pound per square inch	70,000
Yield point (minimum), pound per square inch	50,000
Elongation (minimum), in 2 inch, per cent	10
Reduction of area (minimum), per cent	40

Nuts shall withstand being increased 25 per cent of their original internal diameter without fracture and decreased 25 per cent of their internal diameter without failure.

BALL HEXAGON-HEAD BOLTS AND NUTS

AERONAUTIC



Physical Properties

Assembled bolts shall show required minimum tensile-strength when tested in tension between the head and the nut.

Bolts shall stand cold-bending in the plain part without fracture through an angle of 180 deg. over a diameter equal to the diameter of the bolt. In short bolts the test may be made in threaded part the angle of bend to be through 35 deg.

Marking

Bolts conforming to these specifications shall be marked in some distinctive manner where shown.

Bolts conforming entirely to Army-Navy material specifications shall be marked with X.

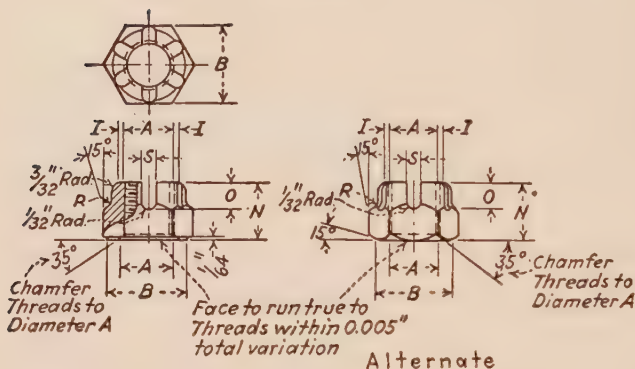
Bolts not marked in either manner will be understood to be made from low-strength material.

Nominal bolt size, <i>A</i>	Threads per inch ¹	Bolt diameter limits, <i>A</i> ²	<i>B</i> , width across flats	<i>C</i>	<i>D</i> , radius	<i>E</i> , width across flats	<i>F</i> , ball hexagon nuts	Ball castle nuts			Tensile strength (minimum)
								<i>G</i> ³	<i>H</i>	<i>I</i>	
0.1640 (No. 8)	36	0.1640 + 0.0000 - 0.0050	$\frac{5}{16}$	$1\frac{1}{64}$	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{64}$	$\frac{1}{4}$	$\frac{5}{64}$	$\frac{5}{64}$	.....
0.1900 (No. 10)	32	0.1900 + 0.0000 - 0.0054	$\frac{3}{8}$	$1\frac{1}{64}$	$\frac{3}{8}$	$\frac{3}{8}$	$1\frac{1}{64}$	$\frac{1}{4}$	$\frac{5}{64}$	$\frac{5}{64}$	2,190
0.2500 ($\frac{1}{4}$)	28	0.2500 + 0.0000 - 0.0062	$\frac{7}{16}$	$1\frac{3}{64}$	$\frac{3}{8}$	$\frac{1}{2}$	$1\frac{3}{64}$	$1\frac{9}{64}$	$\frac{5}{64}$	$\frac{3}{32}$	4,070
0.3125 ($\frac{5}{16}$)	24	0.3125 + 0.0000 - 0.0066	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{1}{4}$	$1\frac{1}{32}$	$\frac{5}{64}$	$\frac{3}{32}$	6,550
0.3750 ($\frac{3}{8}$)	24	0.3750 + 0.0000 - 0.0066	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{16}$	$\frac{7}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	10,100
0.4375 ($\frac{7}{16}$)	20	0.4375 + 0.0000 - 0.0072	$\frac{9}{8}$	$2\frac{3}{64}$	$\frac{1}{2}$	$\frac{5}{8}$	$2\frac{3}{64}$	$3\frac{1}{64}$	$\frac{1}{8}$	$\frac{1}{8}$	13,620
0.5000 ($\frac{1}{2}$)	20	0.5000 + 0.0000 - 0.0072	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{3}{4}$	$\frac{3}{8}$	$\frac{9}{16}$	$\frac{1}{8}$	$\frac{3}{16}$	18,580
0.5625 ($\frac{9}{16}$)	18	0.5625 + 0.0000 - 0.0082	$\frac{7}{8}$	$1\frac{5}{32}$	$\frac{5}{8}$	$\frac{7}{8}$	$1\frac{5}{32}$	$2\frac{1}{32}$	$\frac{5}{32}$	$\frac{3}{16}$	23,600
0.6250 ($\frac{5}{8}$)	18	0.6250 + 0.0000 - 0.0082	$1\frac{1}{8}$	$3\frac{3}{64}$	$\frac{5}{8}$	$1\frac{1}{2}$	$3\frac{3}{64}$	$4\frac{9}{64}$	$\frac{5}{32}$	$\frac{1}{4}$	30,000

¹ Threads are American Standard (NF), with Class 3 tolerances. NF = National Fine pitch.³ *G* = *F* + *I*.² Finished sizes include plating.

CASTLE HEXAGON-NUTS

AERONAUTIC



Bolt size A, threads per inch ⁴	B ¹	N	S +0.010 -0.000	O ²	R	I ³
0.1640 (No. 8)-36	$\frac{3}{8}$	$1\frac{5}{64}$	$\frac{5}{64}$	$\frac{9}{64}$	$\frac{3}{32}$	$\frac{1}{64}$
0.1900 (No. 10)-32	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{5}{64}$	$\frac{9}{64}$	$\frac{3}{32}$	$\frac{1}{64}$
0.2500 ($\frac{1}{4}$)-28	$\frac{7}{16}$	$\frac{9}{32}$	$\frac{5}{64}$	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{1}{32}$
0.3125 ($\frac{5}{16}$)-24	$\frac{1}{2}$	$2\frac{1}{64}$	$\frac{5}{64}$	$\frac{5}{32}$	$\frac{3}{32}$	$\frac{1}{32}$
0.3750 ($\frac{3}{8}$)-24	$\frac{9}{16}$	$1\frac{3}{32}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{32}$	$\frac{1}{32}$
0.4375 ($\frac{7}{16}$)-20	$\frac{5}{8}$	$2\frac{9}{64}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{32}$	$\frac{3}{64}$
0.5000 ($\frac{1}{2}$)-20	$\frac{3}{4}$	$\frac{9}{16}$	$\frac{1}{8}$	$1\frac{3}{64}$	$\frac{1}{8}$	$\frac{3}{64}$
0.5625 ($\frac{9}{16}$)-18	$\frac{7}{8}$	$3\frac{9}{64}$	$\frac{5}{32}$	$\frac{7}{32}$	$\frac{5}{32}$	$\frac{3}{64}$
0.6250 ($\frac{5}{8}$)-18	$1\frac{5}{16}$	$1\frac{1}{16}$	$\frac{5}{32}$	$\frac{7}{32}$	$\frac{5}{32}$	$\frac{3}{64}$

¹ Also size of hexagon.² Also depth of slot.³ Distance from A to beginning of $\frac{3}{32}$ -inch radius, whose center is floating to satisfy curve.⁴ Finished sizes include plating or protective coating.

All threads are American Standard (NF), with Class 3 Tolerances. NF indicates National Fine pitch. Tolerances are ± 0.010 in. except where otherwise indicated.

Physical Properties

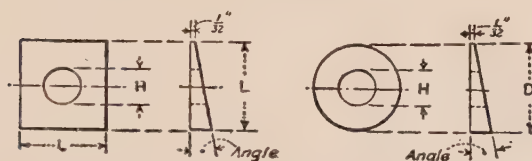
Nuts shall be manufactured from bar steel having the following physical properties:

Tensile strength (minimum) pound, per square inch	70,000
Yield point (minimum) pound per square inch	50,000
Elongation (minimum) in 2 inch, per cent	10
Reduction of Area (minimum) per cent	40

Nuts shall withstand being increased 25 per cent of their original internal diameter without fracture and decreased 25 per cent of their internal diameter without failure.

BEVEL WASHERS

AERONAUTIC



Bolt diameter	H	D	L
No. 4 (0.112)	No. 31 (0.120)	$\frac{3}{8}$	$\frac{3}{8}$
No. 6 (0.138)	No. 26 (0.147)	$\frac{7}{16}$	$\frac{3}{8}$
No. 8 (0.164)	No. 17 (0.173)	$1\frac{5}{32}$	$1\frac{5}{32}$
No. 10 (0.190)	No. 8 (0.199)	$\frac{1}{2}$	$1\frac{5}{32}$
No. 12 (0.216)	No. 1 (0.228)	$\frac{9}{16}$	$1\frac{7}{32}$
$\frac{1}{4}$	$1\frac{7}{64}$	$\frac{5}{8}$	$1\frac{7}{32}$
$\frac{5}{16}$	$2\frac{1}{64}$	$1\frac{1}{16}$	$2\frac{1}{32}$
$\frac{3}{8}$	$2\frac{5}{64}$	$\frac{3}{4}$	$2\frac{1}{32}$
$\frac{7}{16}$	$2\frac{9}{64}$	$1\frac{5}{16}$	$\frac{7}{8}$
$\frac{1}{2}$	$3\frac{3}{64}$	1	$\frac{7}{8}$

Angles: 6, 12, 24, 36 deg. for all sizes.

Faces shall be flat and free from burrs. Bright medium carbon steel shall be used.

SECTION XII

AIRSHIPS OR DIRIGIBLE BALLOONS

While the lighter-than-air craft, commonly known as airships or dirigibles, have not yet made their way into regular commercial use, the voyage of the *Graf Zeppelin* in the fall of 1928 indicates that the possibilities of such use cannot be overlooked. Although many men attempted to use the balloon type of aircraft with little success, we need, perhaps, only consider Count Zeppelin and Santos Dumont, a young Brazilian who made several spectacular flights in France in and around 1901-3. Although Count Zeppelin's work on dirigibles came later, the idea had been in his mind ever since he made balloon ascensions for military observations in Virginia in 1863. He resigned his commission in the German army in 1891 to devote his life to the airships, and though beset by many failures and discredited by all but a few, he persisted in the face of opposition and deserves great credit for his accomplishments.

Airship building in this country has been almost entirely done by the Goodyear Tire & Rubber Company so that the following quotation from its president P. W. Litchfield has the weight of experience behind it.

Airship construction involves the services of the chemist, the metallurgist, the motor builder, the fabric expert, the designer. It calls for calculation of stresses similar to those used in bridge construction but more intricate and complicated. The problem of the airship designer is to build a ship as large as an ocean steamer and yet having the weight of a small channel schooner.

The *Los Angeles* is 656 feet long as against the 900 feet of length of the *Leviathan*, but while the *Leviathan* has a displacement of 60,000 tons, the *Los Angeles* with the maximum lift and load weighs less than 90 tons.

The light internal-combustion engines, together with the development of strong aluminum alloys made possible the modern rigid dirigible. The British, however, are using stainless steel, in special forms, for much of the structural work of their latest airship. Mr. Litchfield

feels that the modern airship will find the three following factors the most important:

The Multiple-cover System.—One light thin cover whose sole function is to hold the lifting gas; a fireproof and waterproof outer cover to form a fair surface; and a stress-taking metal framework between the two. This arrangement of dividing the functions has the advantage that in case of damage one structural part may temporarily take care of the functions of the others.

The multiple-cell system for containing the lifting gas which, like the bulkhead system of the steamship, permits the damage or complete deflation of two or more cells without danger to the ship.

The accessibility of the interior of the ship to inspection and repair even in flight.

There have been important improvements in design. The built-in control car feature is utilized in the *Los Angeles*; a military airship will have its engine cars as well enclosed within the hull of the ship, with only the propellers projecting on outriggers, thus reducing the air resistance and increasing the speed and efficiency. An airship built now would also have tilting propellers turning in a 90-degree arc to help force the ship upward or downward as desired.

The perfecting of the mooring mast largely removes the difficulty of taking a ship in and out of the hangar in a cross-hangar wind. Now a ship can tie up to the mast and wait till conditions are favorable.

In fact, in commercial airship operations, the ship could operate largely from mooring mast to mooring mast, using the hangar only as a surface ship uses the drydock, or the railroad uses the repair shops; that is for overhaul, inspection, and repair. Passengers and freight would be taken to the top of the mooring mast in elevators and embark directly into the nose of the ship. Refueling and even regassing can be carried on at the mast.

The latest and most important improvement in airship design is the substitution of a triple keel for the former single keel, giving great increase in longitudinal strength, similar to the effect of the breaking strength of three lead pencils tied together as against three single pencils. Associated with this is a new type of transverse girder so sturdily built that each section is self-sustaining, so that the failure of one portion of the ship would not endanger the ship as a whole.

Helium gas, such as is used in all the Army and Navy airships in this country, is not obtainable elsewhere. It has the advantage of being non-inflammable and the disadvantage of having considerably less lifting power than hydrogen, which is the gas used elsewhere.

This is a considerable handicap as the airships authorized by Congress with a capacity of 6,500,000 cubic feet will have about the same lifting



FIG. 1.—The Goodyear Puritan, a non-rigid 86,000 cubic foot airship.



FIG. 2.—The Los Angeles landing at Lakehurst on its initial voyage.

capacity as the ships of 5,000,000 cubic feet capacity building in Great Britain. Helium is also considerably more expensive. Some feel,

however, that the growing precautions against fire hazard will bring hydrogen into use in this country, although the first commercial services are likely to use helium, in spite of the increased expense.

The advantages credited to the rigid-framework type of airship are that it can be built in larger sizes, that it is much safer as it divides its

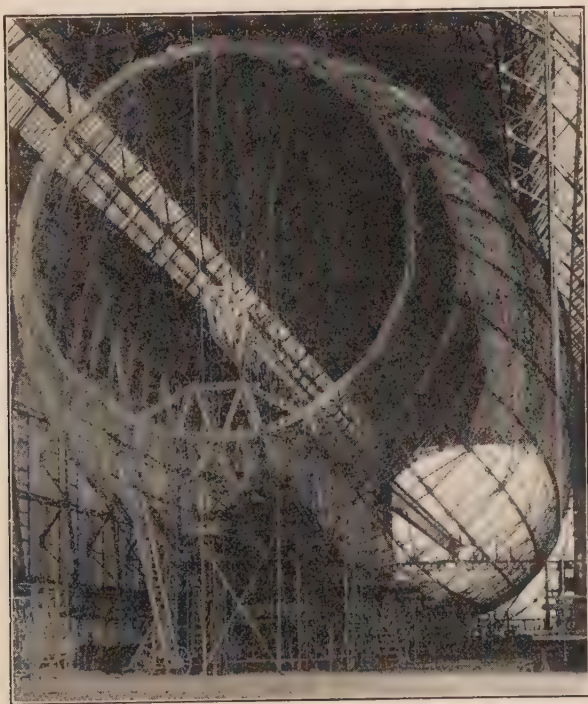


FIG. 3.—Skeleton framework of large rigid airship.

gas capacity among numerous cells. The semi-rigid airship is usually a single-cell craft but has some metal framework, while the non-rigid ships, popularly known as "blimps" (a contraction of their original designation as B-limp type) are virtually free balloons with motors for driving them in the desired direction. As the lifting gas expands and contracts with changes in temperature, the bag of the non-rigid ship

has a smaller balloon or ballonet inside it, this being filled with air. When the gas expands with the heat of the sun or in high altitudes, it forces the air out of the ballonet and so prevents the loss of the expensive helium, or lifting gas. When the gas contracts, air is pumped into the ballonet so as to keep the bag taut at all times.

The smallest, or pony, blimp ever built is believed to be the *Pilgrim* of 35,000 cubic feet, about one-fourth the size of the usual non-rigid.

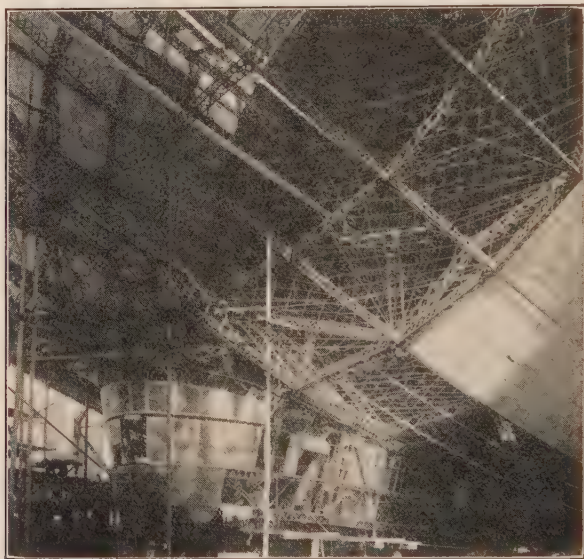


FIG. 4 — Framework with control car attached.

Next came the *Pilgrim* of 50,000 cubic feet capacity, one-fiftieth of the *Los Angeles* and in August, 1928, the *Puritan*, of 86,000 cubic feet which is 128 feet long and 37 feet in diameter.

Notable among the semi-rigid airships was the *Norge* in which the Nobile-Amunsden-Ellsworth expedition flew over the North Pole and which was lost on a later expedition. The first American-built semi-rigid airship is known as the RS-1 and has a gas capacity of 719,000 cubic feet, about one-fourth the size of the *Los Angeles*. It is 280 feet long, has four engines of 300 horsepower each which give it a rated

speed of 70 m.p.h, a cruising radius of 1,100 miles, with a crew of nine men. The RS-1 can act as a mother-ship for airplanes, releasing them and picking them up after a flight. Instead of adding to the load of an airship, as might be supposed, a plane supports itself in the air below the ship, as long as the ship is moving at more than the stalling speed of the plane. For the same reason there is no upward reaction when the plane is released for flight. The only retardation, due to carrying

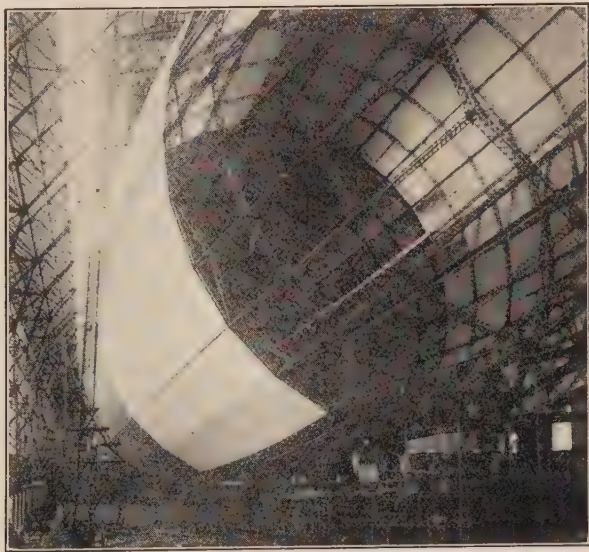


FIG. 5.—Framework rigid ship showing partially covered.

planes suspended, would be the drag through the air. For long flights provisions would be made to carry the airplanes inside the body of the airship.

The illustrations that follow show the Goodyear blimp *Puritan*, in Figs. 1 and 2, the ship that is now the *Los Angeles* landing at Lakehurst after her voyage from Germany. Figures 3, 4, and 5 are views of rigid airships under construction. In Fig. 6 is a composite picture of four sizes of airships, placed together for comparison, as to sizes. The largest, the GZ-1 is one of the two now under construction for the U. S.

Navy. These illustrations are by courtesy of the Goodyear Tire & Rubber Company.

The outstanding airship event of 1928 was, according to C. P. Burgess, Bureau of Aeronautics, U. S. Navy Department, the voyage of the *Graf Zeppelin* with passengers and mail from Friedrichshafen to Lakehurst, N. J. The successful completion of the voyage in spite of bad



FIG. 6.—Comparative sizes of four airships.

weather and an accident to the port-stabilizer fin proved that the airship, like the steamship, has the ability to reach its destination in the face of adverse circumstances. Although the *Graf Zeppelin* took 110 hours it travelled 3,425 nautical miles as compared with the *Mauretania's* record of 122 hours from Sandy Hook to Cherbourg, only 2,925 nautical miles.

The U. S. S. *Los Angeles* also made a notable voyage non-stop from Lakehurst via New York to Panama where it moored to the mast of the *Patoka* off the coast of Cuba and refueled.

The table gives comparisons between the *Los Angeles*, the *Graf Zeppelin*, and the ZRS-4, the latter being the designation of the two new airships being built at Akron by the Goodyear-Zeppelin Corporation for the U. S. Navy. The designs of these ships show a very great advance over any previous airships. They will have a speed of 72.8 knots, and a range of 9,180 nautical miles without refueling at 50 knots speed, as compared with 63.5 knots full speed and 3,500 nautical miles range at 50 knots for the *Los Angeles*. Their hulls will contain hanger space for five small fighting or scouting airplanes.

COMPARATIVE CHARACTERISTICS OF THE AIRSHIPS
Los Angeles, Graf Zeppelin, AND ZRS-4

	Airship		
	Los Angeles	Graf Zeppelin ¹	ZRS-4
Nominal gas volume, cubic feet.....	2,470,000	3,708,000	6,500,000
Length overall, feet.....	658.3	776.2	785
Maximum diameter, feet....	90.7	100.1	132.9
Height overall, feet.....	104.4	110.6	146.5
Gross lift, pounds.....	153,000	230,000	403,000
Useful lift, pounds.....	60,000	108,000	182,000
Number of engines.....	5	5	8
Total horsepower.....	2,000	2,550	4,480
Maximum speed, knots.....	63.5	69.0	72.8
Range at 50 knots, naut. miles.....	3,500	6,850	9,180
Slenderness ratio.....	7.25	7.75	5.90
Ratio of useful to gross lift..	0.39	0.47	0.45

¹ NOTE.—For purposes of comparison, the *Graf Zeppelin* is assumed to be inflated with helium. When inflated with hydrogen and fuel gas, her range at 50 knots is about 9,000 nautical miles.

Names of Parts of Lighter than Aircraft.—The accompanying illustrations, Figs. 7, 8, and 9, show outlines of the non-rigid, semi-rigid, and rigid airships with the names of the main parts, as used by the National Advisory Council of Aeronautics.

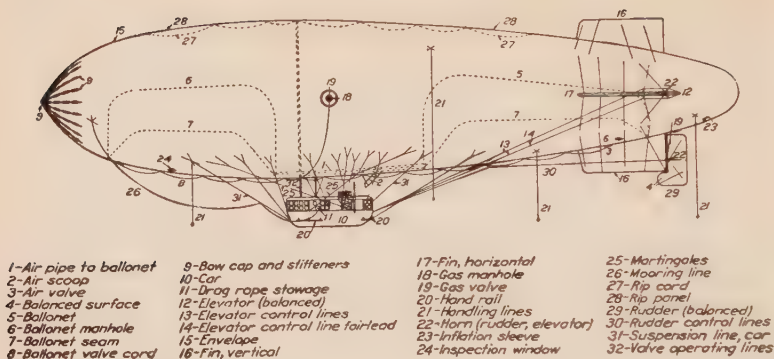


FIG. 7.—Non-rigid airship.

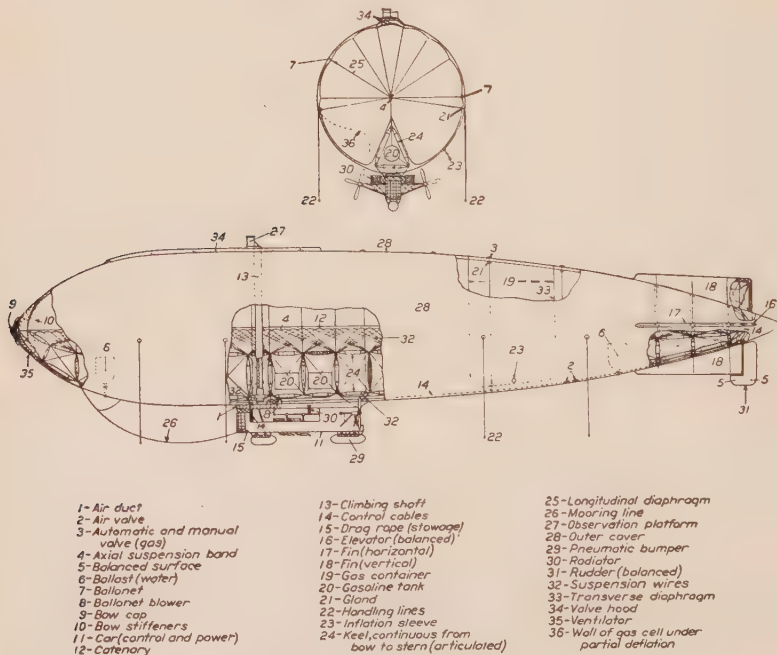


FIG. 8.—Semi-rigid airship.

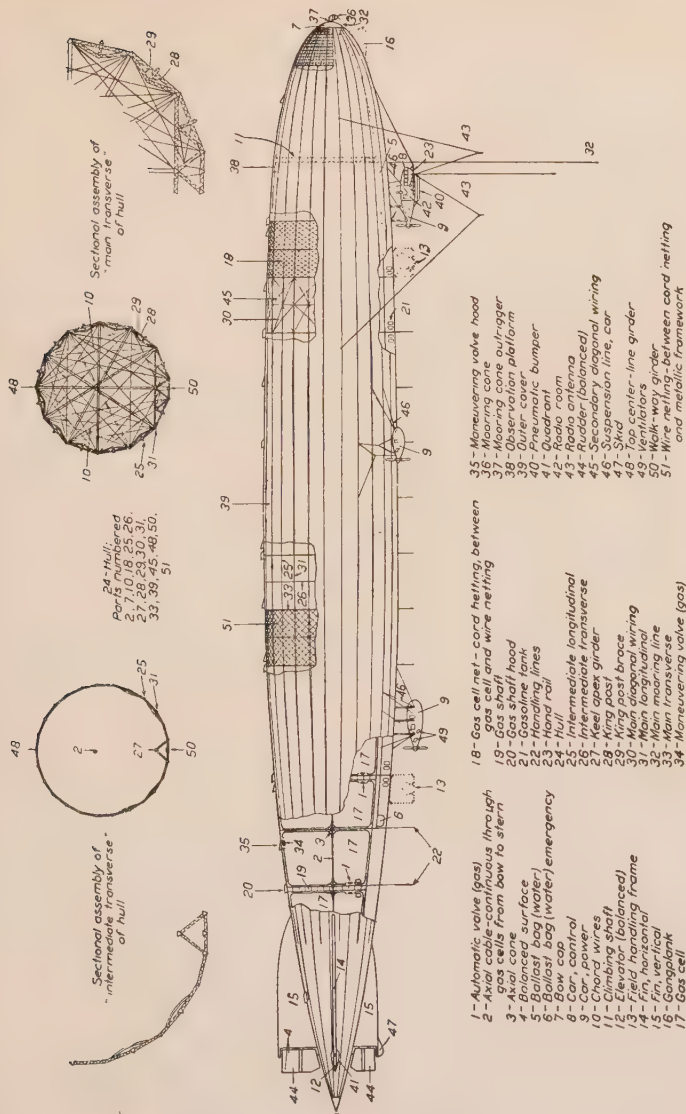


FIG. 9.—Rigid airship.

SECTION XIII

1. CONSTRUCTION OF AIRPORT

An airport means any locality, either of water or land, which is adapted for the landing and taking-off of aircraft and which provides facilities for shelter, supply, and repair of aircraft, or a place used regularly for receiving or discharging passengers or cargo by air.

A landing strip, according to Department of Commerce Airways Division, is an area at least 500 feet wide which forms part of an airport, intermediate or auxiliary field, and which is suitable by natural condition or artificial construction for the landing and taking off of airplanes.

Runway.—An artificial landing strip or portion thereof at least 100 feet wide. When the natural condition of the ground is unsuitable for regular operation of airplanes, artificial preparation is necessary, using crushed stone, crushed slag, or other wear-resisting material in conjunction with a suitable binder, in order to present a satisfactory surface under all ordinary weather conditions. The artificial runway may be laid down upon a landing strip, but it need not cover the entire area of the landing strip.

Two-way, Three-way, and Four-way Fields.—Airports and landing fields are styled two-way, three-way, four-way, six-way, etc., according to the number of directions in which airplanes may land and take off. A rectangular field which permits landing along its longest dimension only is a two-way field, as it may be approached from only two directions. A square field crossed diagonally by two runways provides four-way landing. A triangular field having runways with its sides is a sixway field. The best condition is that realized when a field is available for landing in all directions. Such an airport will be called *all-way*.

NEED FOR AIRPORTS

The necessity for well-designed airports has become apparent with the rapid growth of civil aeronautics. With the increase of air traffic,

cities without airports are finding themselves in the same class as coastal cities without well-equipped, sheltered harbors. Naturally, those cities which possess good airports will attract present and future air commerce. The existence of such airports and the favorable public attitude indicated by such possession will cause cities to be carefully considered as stopping points on the official civil airway of the United States.

The commercial value of an airport is not its only consideration. It has an important value as a recreation facility similar to city parks, golf courses, equestrian trails, bathing beaches, etc., and it should be a municipal enterprise. The Air Commerce Act of 1926 recognizes this by providing that civil airports shall not be owned or operated by the Federal government.

In general, the airport should be large enough for absolute safety of operation, easy of approach from all directions, and quickly reached from the city. It should be planned to care for future rapid increases in aeronautics. At first, the municipal hangars may be available for housing public planes and public transport craft. Later, when traffic becomes too heavy, the municipal airport may become a place for the taking on and discharging of passengers, mail, express, and freight. It will be to the airway what the railroad terminal is to the railways. After unloading, the transport planes will be flown to larger fields on the outskirts of the city, where they will be serviced and held until ready for return trips.

SELECTING THE SITE

Basic Requirements.—The field should be firm, approximately level, well drained, without obstructions or depressions presenting hazards in taking-off and alighting, and with clear and safe approaches. By *hazard* is meant any obstacle, object, or condition that renders operations dangerous under any expected conditions.

If no site can be found to fulfil the highest requirements, then the field should permit the laying out of at least two landing strips 100 or more feet wide, the angle of crossing or converging to be not less than 45 degrees. These landing strips, whether runways or natural surfaces, must permit safe landing under ordinary weather conditions. This includes average rainfall and snowfall.

The field should permit margins of at least 100 feet between the outer edges of the landing strips and the boundaries of the field.

The site should be situated on (or capable of immediate connection thereto) a good highway leading to the nearest city or town.

Prevailing Wind.—The direction of the prevailing wind is always important, as airplanes, in most cases, land directly into the wind. Cross-wind landings can be made in light planes and in heavier planes by expert pilots, but this practice is not recommended, especially in aircraft used for public transportation. When the airport is not available for landing in all directions, the longest landing strip should, when possible, be aligned with the direction of the prevailing wind. If not possible, the nearest approach to this condition should be made.

CONSTRUCTION OF BUILDINGS AND EQUIPMENT

Location of Buildings.—Airport buildings should be arranged along the side of the landing area, where they will interfere least with landing and taking-off. In case of a rectangular field, this will be easy of application, as the buildings can be arranged at the edge of the field. This will not seriously reduce the available landing area, as would be the case if the field were square. Whenever an adjacent strip of land offers possibilities for the sites of hangars, shops, etc., it should be used, rather than have the landing space cut down. There is no recognized form of layout for buildings, as those will vary with each field.

A section of an irregular-shaped field, which would be unavailable for landing, may be used for location of the necessary buildings, thus removing these obstacles from the portion used for operations.

The buildings should be placed most conveniently for connection with water, light, and power mains. They should also be well spaced to reduce fire hazard. Provision should be made for a road to connect with the highway, giving the most direct line without crossing the landing area.

In the larger airports, where there is need for a railroad spur or a siding, the tracks should be laid along the rear of the buildings. To eliminate unnecessary operation on these tracks, the supply buildings should be placed as close as possible to the main line.

All of these considerations should be considered after the most important factor of clear approaches and largest landing area is settled.

Fuel Supply.—The fuel-supply system should be located most conveniently for servicing planes without unnecessary taxing. In small airports, it may be placed near the road, so that gas and oil may be supplied to automobiles also, thus adding to the revenue. In larger airports, a fuel truck may be used, but this will not be warranted in most cases. Ordinarily, the supply tank should be placed underground and at some distance from the outlets. One method is to have a regular filling-station pump connected by piping to a trap containing a coil of hose. Planes can be taxied to the trap, gassed, and moved away under their own power. The trap lid is flush with the field, so that there is no obstruction. At smaller fields, a filling-station pump can be used with only a slightly longer length of hose than that customary for automobiles. The local oil company will usually be willing to install such a pump.

Oil and water can be supplied from the fuel shed, as required. If the field is not near a water main, a well may be sunk. Water containing alkali should not be used for radiators.

Hangars.—The number and size of hangars required depend on the size and importance of the landing field. The number and size of hangars depend upon the expected traffic. It is well to start with a single hangar at least 100 by 60 feet. Others may be added as required.

Where the ground is frequently soft or muddy, the hangars should be connected with landing strips by a specially prepared surface of cinders, concrete, slag, gravel, or other suitable material. Such an area is usually used for blocking up wheels of planes during the "warming-up" process.

Marking.—Roofs of hangars should be properly marked for identification of the airport and for giving such other information as may be necessary. Figure 1 illustrates hangars marked for the guidance of pilots.

Shops.—If air traffic warrants, there should be separate shops. The larger airports will naturally provide for this, but when the initial investment must be held down, the shop may be placed within a hangar, usually at the rear. The kind of machinery, tools, miscellaneous equipment, etc., in the shop depends on the number of planes to be serviced. There should be facilities sufficient to permit change of engines and landing gear as well as minor engine and plane repairs. This does not require any elaborate device. A small derrick or other

lifting apparatus may be used. Block and tackle swung from hangar girders is not recommended, as this may strain the cross-members excessively.

Field Station and Restroom.—The restroom required by the rating regulations may be in the same building as the field station, which serves as an office, weather-information station, and, in some cases, as a waiting room. The bulletin board or other means for giving pilots the latest weather information should be placed in a conspicuous place.



FIG. 1.—Hangar markings in accordance with aircraft regulations—McCook Field, Dayton, Ohio.

The operations manager or, in the case of smaller fields, the man in charge of the airport, should have a clear view of the whole landing area and all buildings. This may necessitate his being stationed in an elevated position, perhaps a small tower having vision in all directions. At the smaller airports, no elaborate tower would be necessary. There should be a telephone at the field station. This office is the point at which all visiting pilots will expect to receive information on the weather and other necessary matters connected with flying in that territory. All activities of the field should be centered and controlled at this office.

Sleeping Quarters.—The sleeping quarters need not conform to any particular standard, so long as they afford reasonable comfort, light and heat, and toilet facilities.

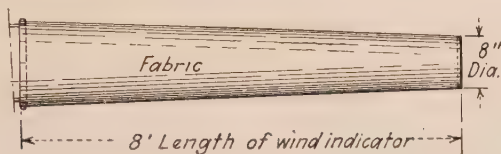


FIG. 2.—Standard wind cone.

Wind Indicator.—A wind indicator is a necessity at all airports and landing fields and is required by the basic regulations. No particular



FIG. 3.—Radio and wind-direction towers, Templehof Airport, Berlin, Germany.

standard is mentioned in the basic requirements, but the type used should give as efficient service as that approved by the Department of Commerce for intermediate fields. This is illustrated in Fig. 2.

Night illumination of the wind indicator and the use of an illuminated wind indicator are discussed under Night Lighting. This approved type of wind indicator is constructed of fabric equal to grade A mercerized-cotton wing fabric and should be white. It should be properly cut, fitted, and strongly stitched. Both ends should be triple lapped and double stitched. Bands at each end should be taped with cotton fabric before fitting and sewing of the wind-indicator cone.



FIG. 4.—Illuminated wind direction T.

Other designs of wind indicators are more elaborate. Figure 3 shows a more expensive type of wind indicator. This is located at Templehof Airport, Berlin, Germany. Any type may be used which will give sufficient aid to pilots in learning the direction of the wind. The illuminated wind T, shown in Fig. 4, is also a good day indicator.

Light and Power Lines.—If it is not possible to place light and power mains underground, the poles should be removed to a safe distance from the boundaries of the landing area or placed in the rear of buildings and not higher than the tops of these buildings. In all cases, poles, cross-trees, transformer boxes, etc., should be painted to give the utmost visibility. Night lighting of these obstructions is discussed under Night Lighting.

Fire-fighting Equipment.—As stated in the rating regulations, there is no definite rule for the fire-fighting equipment needed, as this will vary with each airport in regard to the type of apparatus used. Fire extinguishers of approved type should be readily available in sufficient numbers at hangars, shops, fueling points, and other buildings.

Sand is helpful for extinguishing gasoline or oil fires in hangars or shops. For ordinary fires, there should be sufficient outlets on the water mains to protect all structures. Floors of hangars and shops should be kept clear of grease or covered with sand to reduce fire hazard.

Restriction of Landing and Embarkation Areas.—No one but personnel directly connected with the operation of the airport should be allowed on the landing field proper. The entire area should be fenced. If funds permit, close-spaced wire fencing, or similar barriers, should be used. Protection from propellers in embarking and disembarking areas may be obtained by erecting special enclosures into which the nose of the plane may be taxied, thus cutting off the propeller-swept area from the passengers. Another method provides for barring off the danger area by swinging a long gate against the wheels of the plane.

Protection of Unhoused Planes.—When hangars are not available, there must be some reliable method of securing airplanes to prevent damage by storm. One system is to stretch a tarpaulin over the entire plane, pegging it to the ground on all sides. Another plan is to run lines from the wing tips and the tail to stakes prepared for that purpose. Additional lines may be run to landing gear and struts if a violent storm is expected. Sandbags should be available for weighting down planes in emergencies.

Remote-control Radio.—When a radio station is operated from the airport, it is desirable to have the towers and antennae removed to a safe distance and operated by remote control. The menace of these obstacles is thus eliminated.

DAY SIGNALS AND IDENTIFICATION MARKINGS

Marking of Fields.—Each field, according to the proposed rating regulations, should have a 100-foot circular marker, as in Fig. 5, with a 4-foot band. The name of the field or city should be near the circle. This marker should be placed in the center of fields which are clear for landing in all directions. Figure 6 shows Lunken Field, Cincinnati, Ohio, marked in this manner.

The easiest way to construct this marker and the name is to spade up the ground for the circle and the letters, removing the earth to a depth of about 6 inches. The resulting holes can then be filled with smooth stones to the level of the field, so that planes may pass over them without difficulty. Whitewashing the stones will make a good marker visible from several thousand feet, depending, of course, upon the height of the letters. The minimum height for a letter should be 15 feet. If stones cannot be obtained, concrete may be used without great additional cost.

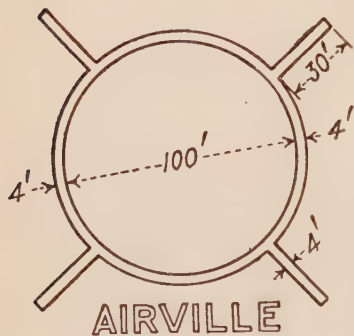


FIG. 5.—Landing field marker with runway indicators.

Local Guides for Pilots.—It is important to have the roofs of factor-

ies, storehouses, or other large buildings in the nearest city marked, so that any pilot reaching a city may find the airport without a prolonged



FIG. 6.—Lunken Field, Cincinnati, Ohio.

search for it. The airport authorities should try to have neighboring villages identified by roof markings, so that pilots may be able to check their courses.

Marking of Runways or Landing Strips.—Where the entire field is not available for landing, the landing strips or runways should be identified and indicated by arms projecting from the circle. In Fig. 5 are shown the dimensions of the arms for marking a standard four-way field with runways or landing strips.

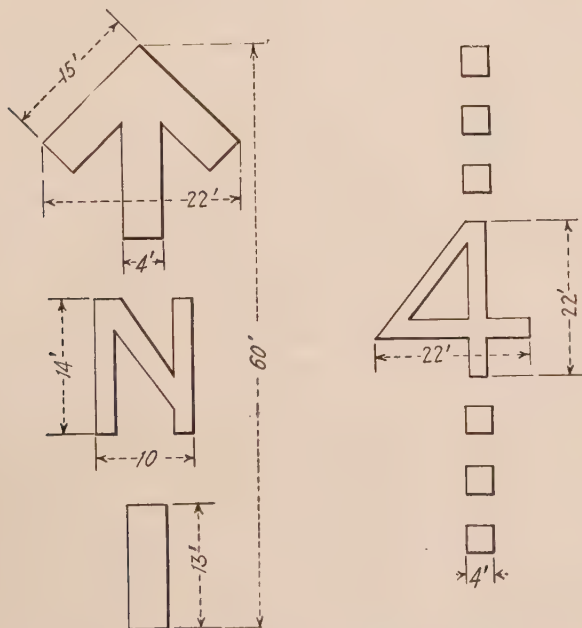


FIG. 7.—Markings showing direction and route number.

Hangar-roof Markings.—Roofs of hangars or other structures on the airport having appropriate areas should be marked as indicated in Fig. 1. The symbols and letters should be made in dull white against a dull black background. The arrow with a letter *N* superimposed should point true north and not to magnetic north. Local surveyors can furnish this direction without difficulty. The letters of the name should be made high enough to afford easy visibility from at least 3,000 feet. Although it is not necessary to have the arrows pointing to other cities, they may be added when there is sufficient space.

Much thought is being given to aiding the airman by the display of suitable signals to give him his location and also to direct him to

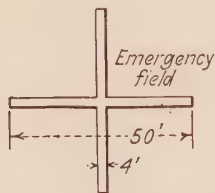


FIG. 8.—Emergency field marker.

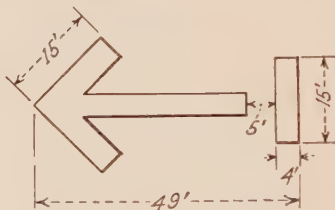


FIG. 9.—Marker pointing to airport.

the nearest airport or emergency landing field. Several suggestions along this line are given in the accompanying sketches. In Fig. 7 the one on the left is a compass direction, showing the north, while the

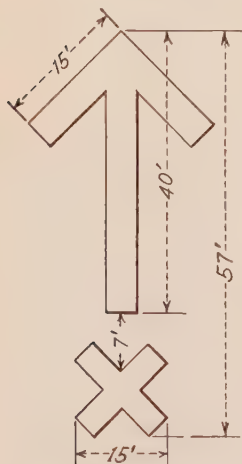


FIG. 10.—Pointer to emergency field.

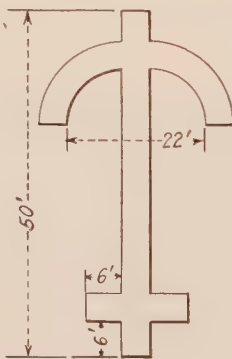


FIG. 11.—Seaplane anchorage.

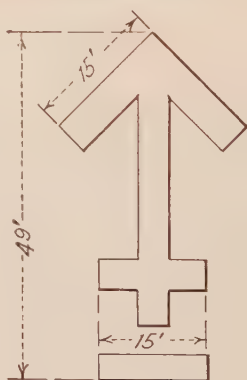


FIG. 12.—Pointer to seaplane anchorage.

other gives a route number, much as the automobilist now finds in all parts of the country. This shows route 4 and the square blocks indicate the direction of the route. Standard landing fields are marked as in

Fig. 5, while Fig. 8 shows an emergency landing field and consists of a cross 50 feet long by 4 feet wide. Figure 9 is a marker pointing the way to an airport, while Fig. 10 points to an emergency landing field; the cross corresponding to the emergency field marking. Figure 11 marks a seaplane anchorage marker and Fig. 12 a pointer to such an anchorage, while Fig. 13 shows the French system of giving the direction and distance; the two dots on each side meaning 22 miles.

While radio communication is the desirable method of information between planes and the ground, some of the transport companies have arranged ground signals that can be seen by pilots if the visibility is good enough. A short-armed white cross, for example, informs the pilot that he is to land for weather reports.



FIG. 13.—French system of giving direction and distance.

NIGHT-LIGHTING SYSTEM

List of Equipment.—The equipment for airports completely lighted for use at night includes the following:

1. Airport beacon.
2. Illuminated wind-direction indicator
3. Boundary lights.
4. Floodlights.
5. Signal lights.
6. Ceiling projector.
7. Hangar floodlights.
8. Auxiliary lights.

Airport Beacon.—The purpose of the airport beacon is to indicate the location of the landing field. It should be installed at such a point as least to obstruct the landing area. It should be mounted on a structural tower with a suitable platform for tending the light, as shown in Figs. 14, 15, and 16, or installed on a tower with a platform surmounting the hangar buildings, the light being at such a height as to project the beam above all surrounding obstructions. The requirement for a beacon light is adequate candlepower and a distinct characteristic. The standard 24-inch revolving beacon has been used with satisfactory results for marking airports. The standard beacon is fitted with a

parabolic mirror and a 1,000-watt, T-20, airway incandescent lamp showing a light of over 2,000,000 candlepower. A recommended addition is a lamp exchanger, which automatically switches a new lamp



FIG. 14.—Airway revolving beacon with wind cone and small power house.
(Courtesy Westinghouse Electric and Manufacturing Co.)

into focus in case of lamp failure. The standard beacon consists of a searchlight drum mounted in a yoke on a base containing a motor and operating gears driving the beacon around the horizon at 6 or 9 r.p.m.

The construction is such that the mechanism should require oiling at infrequent intervals. The beacon is normally elevated at an angle equal to half of the beam spread, so as to project the greatest quantity of light into the sector used by aircraft.

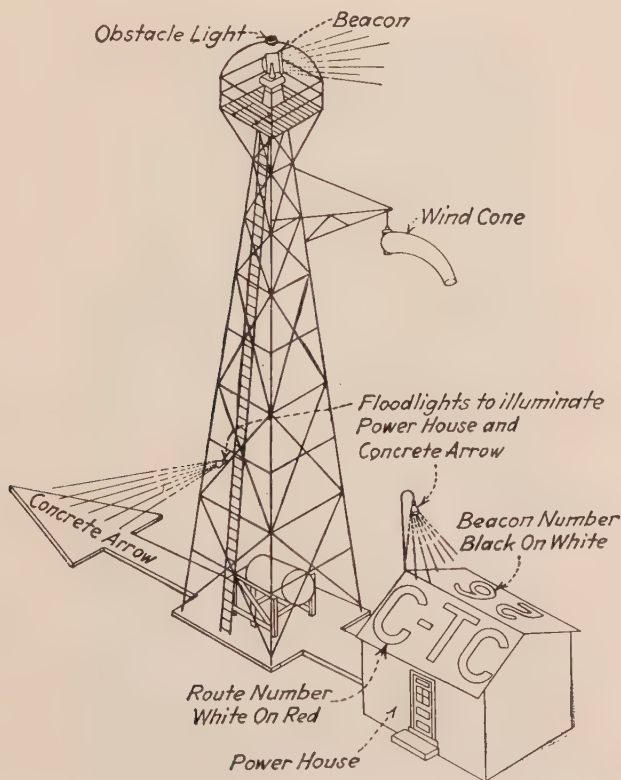


FIG. 15.—Route beacon station for night airways.

Other types of beacon lights meeting these requirements may be used. Commercial current should be used whenever practicable, but pole lines extending commercial current to landing fields should not be installed so as to constitute obstructions. When commercial current

is not available, an engine-driven generating plant may be installed (see Fig. 17).

Ceiling Projector.—A ceiling projector, through a narrow beam of light elevated at an angle of 45 degrees, is used to determine the height



FIG. 16.—Sperry 24-inch rotating beacon.

of clouds, fog, or mist at an airport. The height is determined by pacing the distance from the projector to a point directly under the light spot appearing on the clouds or fog. This distance X is equal to the ceiling height. The apparatus used is a narrow-beam incandescent

projector approximately 12 to 18 or 24 inches in diameter, with a parabolic mirror and a 100-watt concentrated filament lamp. The ceiling projector should be fitted with stray-light shields so as to concentrate the beam.

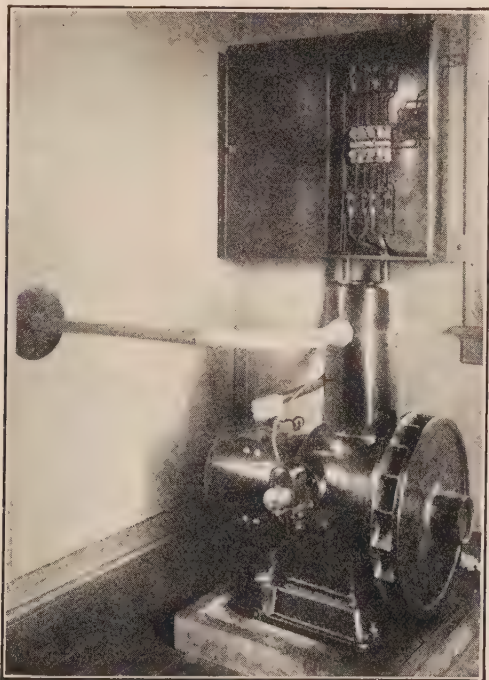


FIG. 17.—Westinghouse generating equipment for isolated searchlight beacons.

The standard illuminated wind cone can be mounted in a suitable location on top of the hangar or on a side bracket attached to the beacon tower, as in Fig. 14. The wind cone ordinarily used is from 18 to 30 inches in diameter at the throat, from 8 to 12 inches at the tail, and from 8 to 16 feet long. It is constructed of No. 1 mercerized-cotton wing fabric treated with a chrome-yellow dye so as to increase its visibility. The wind cone is mounted so as to fly with the wind, suitable brass or galvanized fittings being used to permit rotation.

The wind cone may be internally or externally lighted. The internally lighted wind cone is a lamp mounted at the throat with a suitable reflector throwing the light into the cone. The wind cone will revolve and indicate the direction of the wind. A slipping assembly is used for carrying the current to the lamp. A lamp of not less than 200 watts in the reflector is required. When the cone is externally lighted, a number of reflectors are mounted on the standard above the wind cone, the light being projected downward, thus flood-lighting the cone. This is usually not so satisfactory as the first method.

Another type of wind-indicating device utilizes fixed and flashing green lights mounted on a suitable vane showing the direction of the wind. In the case of the flashing light, the speed of the wind is shown by a device which revolves at a rate of speed commensurate with the wind velocity and eclipses the light.

Boundary Lights.—White boundary lights, such as are shown in Figs. 18 and 19, show the outline of the landing field. They should be spaced not more than 250 feet apart and closer spaced in the case of smaller fields. The circuit for the boundary lights may be series or multiple type. When floodlight units are installed in the boundary circuit, the series circuit with a constant-current transformer is probably the more economical. In series lighting, a safety coil should be installed at the base of the boundary-light standards, so as to prevent contact with high-tension current in the event of a collision, or else each light in the series circuit should be mounted in a series film cutout Mogul

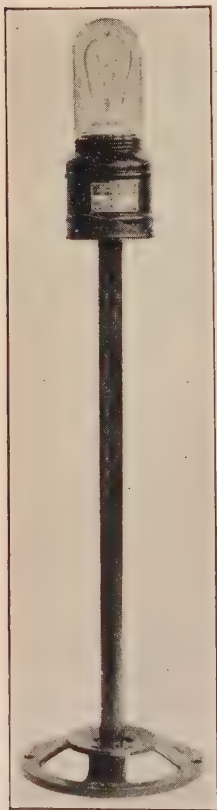


FIG. 18.—Boundary light. (Courtesy General Electric Co.)

socket. The lamps used in connection with series lighting should be 600-lumen, S-24½, 6.6-ampere street-lighting lamps. The standard boundary globes should be of opal glass, if clear lamps are used, so as to prevent glare. In series light, the circuit is carried around the field,

using 2,500-volt No. 8 B. & S. cable. High-tension current up to 2,300 volts is used in the series circuits.

When the multiple circuit is used, the electric lamps of the boundary lights should not be less than 25 watts in size, and the inside frosted type mounted in boundary fittings, having clear-glass globes. The Holophane units for boundary lighting are very satisfactory. At the extremity of landing strips, green lights should be installed, giving

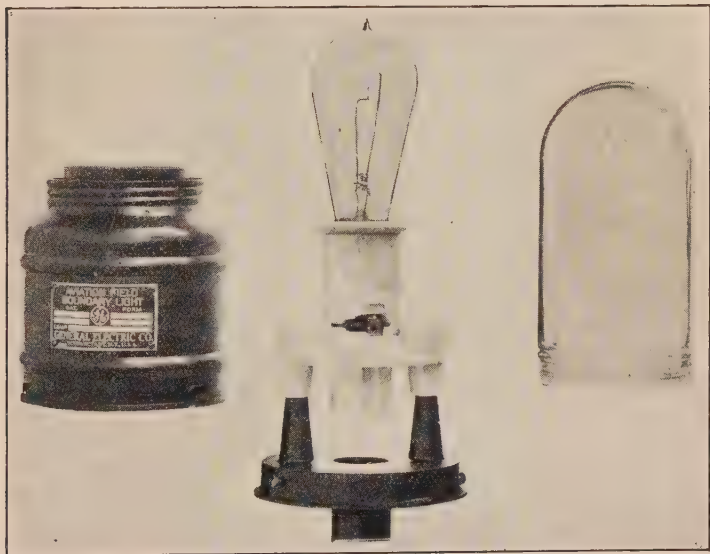


FIG. 19.—Construction of boundary light. (Courtesy General Electric Co.)

the range of the landing direction and showing the best approaches to the landing field. On the sites having obstructions, preventing an approach from that direction, red lights should be installed in the boundary-lighting system. Larger-wattage lamps should be used, in connection with colored lights, so as to show the same brightness as the boundary lights. Pilots unfamiliar with the landing field will thus be given necessary information in regard to the best landing conditions.

Floodlights.—Airports should be floodlighted for night landing. Ground-surface conditions shall determine what method of floodlighting

is most desirable. The equipment and installation shall meet the following requirements:

1. Elimination of glare and of blinding of pilot.
2. Properly directed light from correct height.
3. Adequate light uniformly distributed.
4. Elimination of shadows.

Light projected on a field grazes the surface, and particles, such as pebbles, blades of grass, etc., facing the light are illuminated to a greater extent than horizontal surfaces. Floodlights are therefore elevated slightly but not to an extent that will create a glare or blind the pilot.



FIG. 20.—Floodlight-Fresnel lens type. (Courtesy General Electric Co.)

The ground color will vary, causing a different degree of illumination, depending upon the color, and this fact should be considered in determining the lighting requirements. The amount of illumination required for night landing should approximate $\frac{1}{4}$ foot-candlepower. The lights should be fitted with louvers to prevent the upward-diversion of light. A sharp cutoff is essential.

There are several types of floodlighting equipment available. One type is a large, dioptric Fresnel lens with a high-intensity arc or a 5- or 10-kilowatt incandescent lamp. The distribution of light is shown

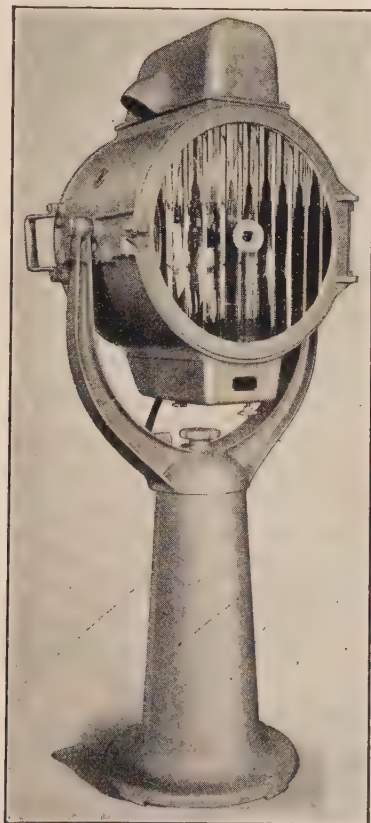


FIG. 21.—Sperry landing floodlight.

in Fig. 20. The equipment is installed in such a manner that no stray light is included upward to blind the pilot. The lens is elevated from 5 to 15 feet above the ground, and the light projected through the Fresnel lens through a horizontal angle of 180 degrees, illuminating the

entire field. A narrow screen is sometimes installed to provide a dark sector in the direction of aircraft about to land, and this screen is adjusted



FIG. 22.—Effect of floodlight on airplane.

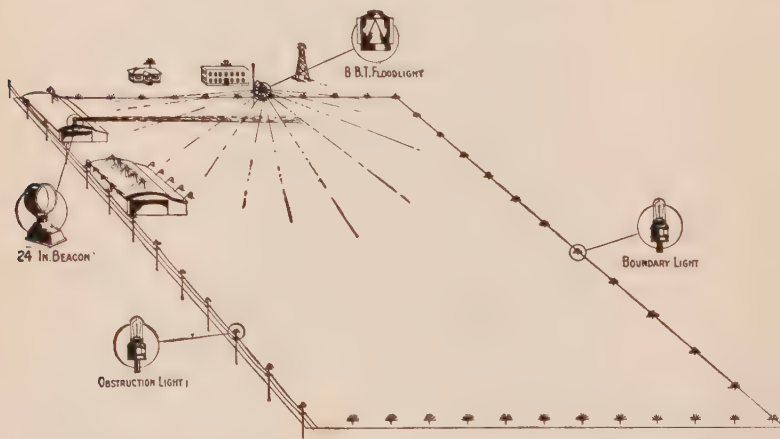


FIG. 23.—Typical airport lighting. (Courtesy General Electric Co.)

to meet varying conditions. Similar apparatus is sometimes mounted on a chassis and moved to any desired location.

Another type of landing-field floodlighting equipment is the 24-inch parabolic reflector unit with a 40-degree spreadlight lens installed (Fig. 21). The lamp is a 1,500-watt, concentrated-filament incandescent lamp. The floodlights are grouped along the sides of the field, the landing of the aircraft taking place in a direction at right angles to the projected light as in Fig. 22. When economy is a necessity, the lights in two of the four sides may be eliminated, the lights being grouped according to the prevailing winds. When landing becomes necessary in a direction at right-angles to the prevailing wind, the lights along one side are extinguished so that the aircraft will not land into the light.

The installation of landing-field floodlights should be made in accordance with the recommendations of the equipment manufacturer. Figure 23 shows typical airport lighting.

Signal Lights.—For communication between airports and airplanes, there should be installed an efficient means of signaling, with a standard set of signals giving necessary information in regard to weather, landing conditions, etc. A suggested system is to have a panel containing a number of electric lights wired so that different units may be switched on so as to show distinct symbols. The panel should be placed in a conspicuous position on the roof of a hangar or other suitable location. The Department of Commerce has worked out a system capable of being used for day and night signalling.

Hangar Floodlights.—The exterior of each hangar should be flooded with a system of lights, to assist the pilot to judge his elevation above the field when landing at night. The sides of the buildings, as well as the roofs, should be floodlighted. The usual floodlighting equipment is a system of industrial reflectors with 200- or 300-watt lamps, a number of floodlight projectors, or a combination of both. The industrial reflectors are made of various shapes to direct the light in the most advantageous manner to illuminate the surfaces required. The industrial reflectors are usually mounted about 10 feet above the roofs of the hangars and buildings should be air marked to show the name of the airport which is floodlighted at night. Hangar sides should be painted white so as to reflect the lights from the floodlighting equipment. If the airport is not located on an airway, an arrow should be installed to show the direction and distance to the nearest beacon on the airway.

Auxiliary Lights.—All obstructions on or near the airport, such as poles, windmills, buildings, etc., should be surmounted by red obstruc-

tion lights in fittings similar to the light standards, as shown in Figs. 18 and 19. Major obstructions, such as radio masts, should be marked by flashing red lights 60 to 100 flashes per minute.

Two-color Airport Beacons.—A new beacon by the General Electric Company (Fig. 24) incorporates two fundamental principles of lighting, each a distinct aid to night flying. It provides a fan of light through

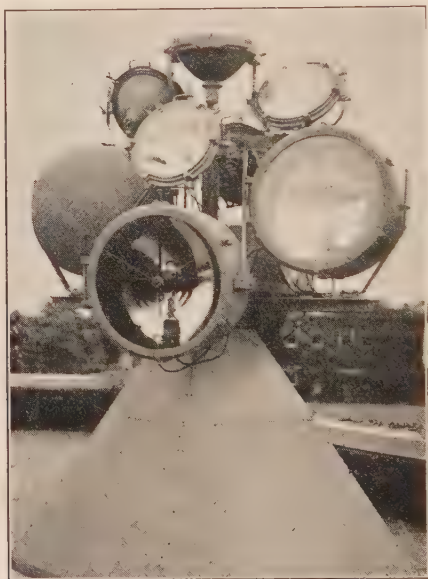


FIG. 24.—Two-color airport beacon.

180 degrees in a vertical plane and this plane rotates about a vertical axis enabling the pilot to see the unit from any angle at which he may approach the field. Opposite each white light there is a red light, aimed in a similar direction, thus providing a color which by its distinctiveness enables the pilot to identify an airport, as colors can be chosen to distinguish airports located near together, from each other. Many pilots have commented favorably on this unit, one of which is located at the Cleveland Airport.

SEAPLANE PORTS AND ANCHORAGES

The selection and equipment of a seaplane port are treated separately from landing fields, although the general requirements are similar.

The port should be located on or directly connected with a body of water calm enough for operations in all but violent weather. The area should be sufficiently large and deep to permit landing and taking-off of seaplanes and flying boats without hazard. If the point at which the hangars are located is adjacent to a small body of water suitable only for taxiing to the larger body, the connecting stream or canal should not be so long as to require excessive taxiing, with consequent overheating of engines.

The general rules as to obstacles, prevailing wind, proximity to city, transportation and communication, light, power and water mains, and clear approaches, previously outlined for land airports, apply equally to seaplane ports. In addition to obstacles in landing and taking-off, the matter of obstructions in or under the water should be carefully considered. The minimum satisfactory depth for operation of flying boats is 6 feet. Rise and fall of tide at coastal ports should be considered in this connection.

Department of Commerce Regulations covering both landing fields and seaplane anchorages follow:

BASIC REQUIREMENTS FOR RATING OF AIRPORTS FOR LAND-PLANES

The minimum basic requirements for the rating of airports are as follows:

(a) *Suitable Landing Area*.—The airport shall afford a firm, smooth, well-drained landing area, approximately level, without obstructions or depressions presenting hazards in taking off or landing, and with suitable approaches. If sufficient area is not available for landing and taking off in all directions, there shall be at least two landing strips 500 feet or more in width crossing or converging at an angle or not less than 60 degrees. The landing area shall permit safe landing and taking off under all ordinary weather conditions. If the surface of the landing area is not sufficiently firm and well drained for this purpose, runways shall be constructed as hereinafter specified. Roads shall not cross any part of the landing area, whether open field or landing strips, and stock and unauthorized persons and vehicles shall not be allowed on the landing area, as this area must be

kept clear and ready for use at all times. The maximum slope of the landing area shall at no point exceed 3 inches in 10 feet, which corresponds to a grade of $2\frac{1}{2}$ per cent. The mean slope of the landing area shall not be more than 2 per cent in any direction.

(b) *Freedom from Obstructions*.—For fields located at sea level, surrounding obstructions diminish the effective landing lengths for planes landing or taking off over these obstructions by amounts equal to seven times the height of the obstructions above the landing area, said distances being measured, in each case, horizontally from vertical lines passing through the

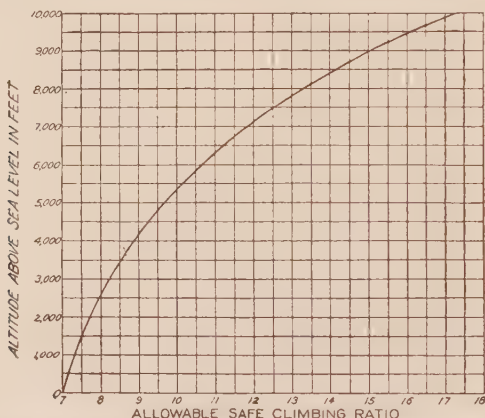


FIG. 25.—Allowable safe landing ratios for clearing obstructions at altitudes above sea level, based on a ratio of 7 to 1 at sea level.

critical points of the obstacles. For instance, obstacles 50 feet high along the border of a field diminish the effective landing length for planes landing or taking off over these obstacles by 350 feet. In the case of landing strips, the presence of obstacles in the approaches will likewise diminish the effective lengths of the landing strips. Where obstacles lie alongside the landing strips, so that planes landing pass parallel to and not over them, the obstacle rule of 7 to 1 will not apply, providing that no landing strip shall be less than 500 feet wide, in accordance with paragraph (a) of basic requirements. However, the location of buildings or other obstructions in the V formed by landing strips or runways is subject to a number of objections.

For fields located at altitudes in excess of 1,000 feet above sea level, the allowable safe-climbing ratios for clearing obstructions shall be increased from the value of 7 to 1 used at sea level to the values shown in Fig. 25.

(At altitudes above sea level, airplanes land and take off at higher speeds and climb at flatter angles than at sea level.)

(c) *Accessibility*.—The airport shall be situated on a good road leading to the nearest city or town.

(d) *Wind-direction Indicator*.—The airport shall be equipped with an approved type of wind-direction indicator, as hereinafter specified.

(e) *Markings*.—The landing area shall be marked by means of a circle at least 100 feet in diameter having a band 4 feet wide, constructed of crushed rock, gravel, or other suitable material as in Fig. 5. The circle shall be finished flush with the surrounding surface and unless constructed of a bright white material shall be kept whitewashed or painted chrome yellow. In case the circle is constructed of concrete or other similar material, shoulders of some granular material, such as crushed stone or crushed slag, or other suitable means shall be provided on both the inside and outside of the circle in order to insure the safe landing and taxiing of planes across the circle in any direction.

The name of the city or town shall be placed near the marker circle (name should not be placed inside of circle) or on the roof of at least one airport building, or on other suitable area, in such manner as to be visible from an altitude of at least 2,000 feet. (Lettering should be from 10 to 30 feet in height as space may permit.) In no case shall the height of the lettering be less than 6 feet. In case the name of the city or town or any other marking is placed on the landing area, it shall be constructed and maintained in the manner hereinabove required for the marker circle.

(It is recommended that, wherever practicable, a combination of chrome yellow and dead black be used in air-marking roofs and other similar areas and that, particularly in cases where the markings are to be illuminated, the chrome yellow be used for the lettering and other symbols, and the dead black for the background.)

The outline of the usable portion of the landing area shall be marked by means of painted galvanized sheet-metal cones not less than 36 inches in diameter at the base by 24 inches in height, or solid 4-foot white or chrome yellow circles constructed of crushed stone, gravel, or other suitable material, or by means of other markers of equivalent effectiveness, placed not more than 300 feet apart along the borders and kept whitewashed or painted. In case the landing area is boundary-lighted, the markers shall be constructed around the boundary lights. In case sheet-metal cones are used, they should be painted in accordance with the following standard system of marking: For either white or yellow lights, chrome yellow with an 8-inch horizontal dead black stripe 9 inches from the base of the cone. For green lights, eight equal segmental elements, alternating chrome yellow and dead black, each element covering a 45-degree segment of the surface. For red lights, light

vermillion with an 8-inch horizontal white stripe 9 inches from the base of the cone. These figures are for cones measuring 36 inches in diameter at the base by 24 inches in height; if cones of larger dimensions are used the width of horizontal stripe and height of stripe above base of cone should be varied accordingly.

Any parts of the landing area temporarily unsafe for landing, or which are not available for any cause, shall be clearly marked with red flags of sufficient size to draw attention readily and so placed as to show the boundaries of the danger area. In case the airport is lighted for night operation the boundaries of such danger area shall be clearly marked throughout the hours of the night (from sunset until sunrise) either with red electric lights with weatherproof fittings or with red lanterns.

(f) *Runways*.—Runways shall be constructed of some wear-resisting material, such as crushed stone, crushed slag, or other suitable material, in such a manner as to give a smooth, firm, uniform surface. (This includes such types of construction as bituminous macadam, bituminous concrete, Portland cement concrete, etc.) Runways shall be so designed and constructed as to withstand safely the loads to which they will ordinarily be subjected. They shall permit safe landing and taking off under all ordinary weather conditions and shall be not less than 100 feet in width. The edges of the runways shall be flush with the adjacent surfaces of the field, and shoulders of some granular material, such as crushed stone or crushed slag, or other suitable means shall be provided in order to insure the safe landing and taxiing of planes across the runways in any direction.

(g) *Drainage*.—The landing area shall be adequately drained whether runways are used or whether the entire field is available for landing and taking off. If the natural drainage is sufficient, no artificial drainage system will be required.

(h) *Fuel, Communication, Transportation, and Personnel*.—The airport shall be provided with facilities for supplying aircraft with fuel, oil, and water, also drinking water shall be available. If there are no restrooms on the airport a suitable latrine shall be provided. The airport shall have dependable communication and transportation facilities to the nearest city or town. Airport personnel shall be in attendance by day or available on call by telephone at the airport. In the latter case, a directory and full instructions for reaching such personnel shall be available in the telephone booth or receptacle.

RATING ON GENERAL EQUIPMENT AND FACILITIES

A-Rating.—In addition to the facilities named in the basic requirements, airports receiving an A rating on general equipment and facilities shall have the following:

(a) At least one hangar measuring not less than 80 by 100 feet in the clear inside with doors open, with 18 foot overhead clearance, with fullwidth door opening in either one or both ends or one or both sides, and with safe provision for heating water and oil. In localities where freezing temperatures are experienced the hangar shall be heated sufficiently to prevent freezing of water.

(b) One or more wind-direction indicators of an approved type, equivalent in effect to a wind cone not less than 12 feet long, 36 inches in diameter at the throat, 12 inches in diameter at the tail, constructed of open-weave unbleached yellow muslin, and so mounted as to fly freely with the wind. This wind-direction indicator shall be so located as to give a true indication of the direction of the wind on the landing area and as to be readily visible to aircraft approaching the airport from any direction. In case it is not visible to aircraft approaching from any direction such additional wind-direction indicators shall be installed as may be necessary.

(c) All telephone and transmission-line poles, radio towers and masts, transmission towers, flag poles, and similar obstructions in the immediate vicinity of the airport shall be day marked by painting with alternate bands of either chrome yellow and dead black, or white and dead black, terminating with either a chrome-yellow or a white band at the top, depending on the color combination used. The width of the bands shall be one-fifth of the height of the structure for all structures less 250 feet high and for structures over 250 feet high, the bands shall be 50 feet wide. Such structures as chimneys and water towers in the immediate vicinity of the airport are not required to be painted in this manner unless, in the opinion of the Secretary of Commerce, such painting is necessary from the standpoint of safety.

The posts of landing-area fencing shall be painted either chrome yellow or white.

(d) Repair equipment sufficient to permit changing of engines and landing gear and equipment for major engine and plane repairs.

(e) Weather instruments, including an anemometer, barometer, and thermometer. There shall also be a bulletin board and facilities for giving pilots the most recent weather information.

(f) Radio-receiving set and loud speaker, under certain conditions, as follows: Airports located within a radius of 400 miles of Department of Commerce Airways radio stations shall be equipped with suitable radio-receiving sets with loud speakers, in order that those using the airport may avail themselves of the hourly weather reports broadcast from said stations. As additional Airways radio stations are installed by the Department of Commerce, airports located within a radius of 400 miles of such stations and previously granted an A rating on general equipment and facilities shall provide themselves with suitable radio-receiving sets and loud speakers in order to retain this rating.

(g) Adequate equipment for removing snow from landing areas or landing strips or equipment for packing snow sufficiently to permit safe landing and taking off of aircraft. (This will not be required at airports where snowfall is never sufficient to cause difficulty in operation).

(h) First-aid equipment consisting of an ambulance, or some vehicle which can be used as an ambulance, equipped with the following: First-aid kit, drinking water, crowbar, wire cutters, hack saw, ax, cloth-cutting shears, fire extinguisher, two litters.

The first-aid kit should contain 12 assorted bandages, 12 sterile dressings, 2 tourniquets, a supply of first-aid dressings for burns, adhesive tape, a supply of either tincture of iodine or mercurchrome, aromatic spirits of ammonia, and a paper or glass cup.

The litters should preferably be of the Stokes Navy type. If they are of the ordinary type, then the vehicle should also carry an assortment of splints.

(i) A register of arriving and departing aircraft to include the following information:

1. License number and model of arriving or departing plane.
2. Owner of the plane.
3. Pilot of plane and his license number.
4. Time of arrival and departure.
5. Number of crew.
6. Number of passengers.
7. Space for remarks covering an unusual situation.

(j) *Adequate Fire-fighting Equipment.*—As this depends on the size and number of buildings, spacing of structures, type of construction, etc., no definite rule can be made which will apply to each case, but such rating will depend upon recommendation of the department representatives, who will be guided in a large measure by the standards of the National Board of Fire Underwriters.

(k) Sufficient personnel in attendance throughout the day to give proper operation of the airport, including servicing aircraft, making major repairs, giving weather service, and operating the fire-fighting equipment.

(l) Sleeping quarters for at least three men, in addition to the field personnel, at the airport or not more than one-half mile distant.

(m) Waiting and rest rooms on the field.

(n) A restaurant or other public source of food supply. (If not actually on the airport, this shall be not more than one-half mile distant.)

B-Rating.—In addition to the facilities named in the basic requirements, airports receiving a B rating on general equipment shall have the following:

(a) At least one hangar measuring not less than 60 by 80 feet in the clear inside with doors open, with 14-foot overhead clearance, with full-width

door opening in either one or both ends or one or both sides, and with provisions for heating water and oil as required for an A rating.

(b) Wind-direction indicator, day marking of obstructions, weather instruments, adequate equipment for removing snow, first-aid equipment, fire-fighting equipment, and a register, all as required for an A rating.

(c) Repair equipment sufficient to permit changing of engines and landing gear and equipment for minor engine and plane repairs.

(d) Sufficient personnel in attendance throughout the day to give proper operation of the airport, including servicing aircraft, making minor repairs, giving weather service, and operating the fire-fighting equipment.

(e) Sleeping quarters for at least two men, in addition to the field personnel, at the airport of not more than one-half mile distant.

(f) Restroom.

C-Rating.—In addition to the facilities named in the basic requirements, airports receiving a C rating on general equipment shall have the following:

(a) At least one hanger measuring not less than 50 by 60 feet in the clear inside with doors open, with 12-foot overhead clearance, with full-width door opening in either one or both ends or one or both sides, and with means for heating water and oil as required for an A rating.

(b) One or more wind-direction indicators as required for an A rating, except that wind cone shall be not less than 9 feet long, 24 inches in diameter at the throat, and 10 inches in diameter at the tail.

(c) First-aid equipment, fire-fighting equipment, and a register as required for an A rating. (The day marking of telephone and transmission-line poles and similar obstructions in the immediate vicinity of the airport as required for the A and B ratings is not required for either the C or D ratings, but is most urgently recommended.)

(d) Restroom.

D-Rating.—Fields which do not possess sufficient general equipment to obtain A, B, or C ratings, but which meet the basic requirements, will receive a rating of D on general equipment.

RATING ON SIZE OF EFFECTIVE LANDING AREA

1-Rating.—In addition to the basic requirements, an airport receiving a "1" rating on size of effective landing area shall have at least 2,500 feet of effective landing area in all directions, with clear approaches, and the field shall be in good condition for landing at all times; or it shall have landing strips not less than 500 feet wide, permitting landing in at least eight directions at all times, the landing strips not to cross or converge at angles of less than 40 degrees, nor any one of the landing strips to be less than 2,500 feet in effective length, with clear approaches.

By clear approaches is meant absence of buildings, towers, and other obstacles over which a 7 to 1 glide or climb to or from the edge of the landing area would not be possible, and absence of smokestacks, towers, high tension power lines, etc., which constitute menaces even though beyond the 7 to 1

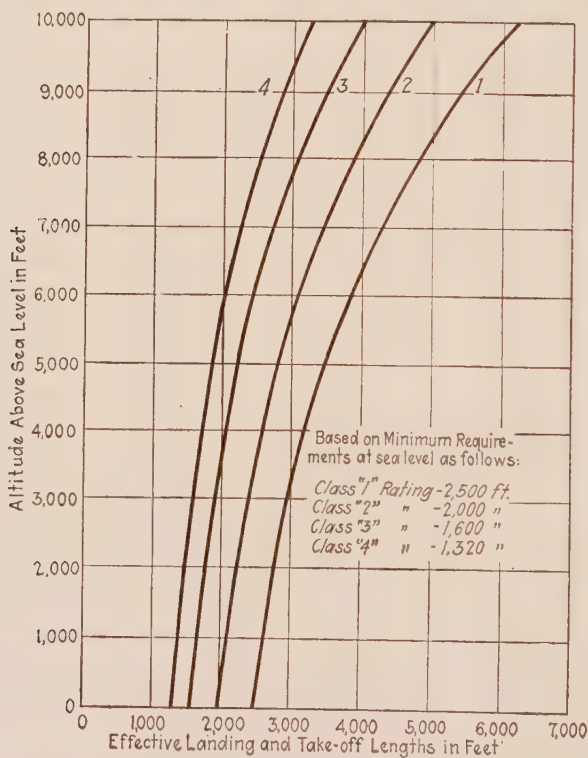


FIG. 26.—Required effective landing and take-off lengths for all-way and light-way landing areas at altitudes in excess of 1,000 feet above sea level.

ratio. See Fig. 25, p. 568 for increase in allowable safe-climbing ratio for altitudes in excess of 1,000 feet above sea level.

When the airport lies at an altitude in excess of 1,000 feet above sea level, the dimensions of the effective landing area or the effective lengths of the landing strips shall be increased to the corresponding values shown in Fig. 26.

2-Rating.—In addition to the basic requirements, an airport receiving a 2-rating on size of effective landing area shall have at least 2,000 feet of effective landing area in all directions, with clear approaches, and the field shall be in good condition for landing at all times; or it shall have landing strips not less than 500 feet wide, permitting landing in at least eight directions at all times, the landing strips not to cross or converge at

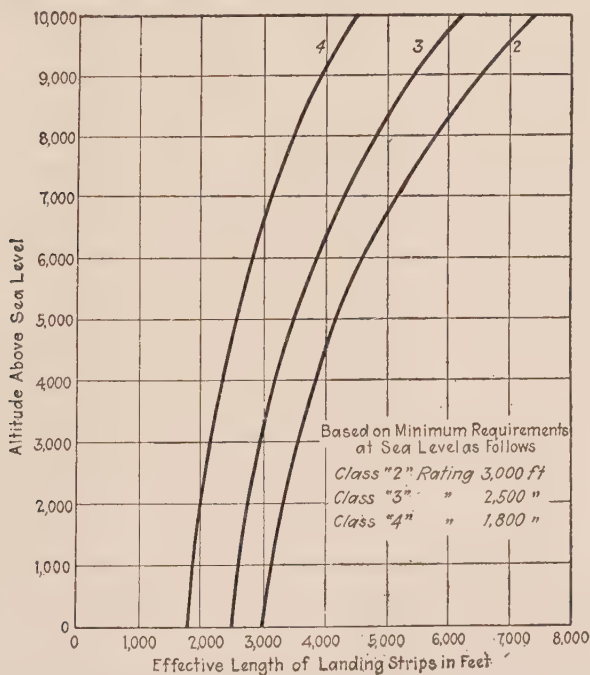


FIG. 27.—Required effective length of landing strips for four-way landing areas at altitudes in excess of 1,000 feet above sea level.

angles less than 40 degrees nor any one of the landing strips to be less than 2,000 feet in effective length, with clear approaches; or it shall have two landing strips, one aligned with the general direction of the prevailing wind, permitting at least four-way landing at all times and having clear approaches, the landing strips to be at least 500 feet wide and not less than 3,000 feet in effective length and not to cross or converge at an angle of less than 60 degrees.

The dimensions of the effective landing area and the effective lengths of the landing strips shall be increased at altitudes above 1,000 feet to the corresponding values shown in Figs. 26 and 27.

3-Rating.—In addition to the basic requirements, an airport receiving a 3-rating on size of effective landing area shall have at least 1,600 feet of effective landing area in all directions with clear approaches, and the field shall be in good condition for landing at all times; or it shall have landing strips not less than 500 feet wide, permitting landing in at least eight directions at all times, the landing strips not to cross or converge at angles less than 40 degrees nor any one of the landing strips to be less than 1,600 feet in effective length, with clear approaches; or it shall have two landing strips, one aligned with the general direction of the prevailing wind, permitting at least four-way landing at all times and having clear approaches, the landing strips to be at least 500 feet wide and not less than 2,500 feet in effective length and not to cross or converge at an angle of less than 60 degrees.

The dimensions of the effective landing area and the effective lengths of landing strips shall be increased at altitudes above 1,000 feet to the corresponding values shown in Figs. 26 and 27.

4-Rating.—In addition to the basic requirements, an airport receiving a 4-rating on size of effective landing area shall have at least 1,320 feet of effective landing area in all directions, with clear approaches, and the field shall be in good condition for landing at all times; or it shall have landing strips not less than 500 feet wide, permitting landing in at least eight directions at all times, the landing strips not to cross or converge at angles less than 40 degrees nor any one of the landing strips to be less than 1,320 feet in effective length, with clear approaches; or it shall have two landing strips, one aligned with the general direction of the prevailing wind, permitting at least four-way landing at all times and having clear approaches, the landing strips to be at least 500 feet wide and not less than 1,800 feet in effective length and not to cross or converge at an angle of less than 60 degrees.

The dimensions of the effective landing area and the effective lengths of the landing strips shall be increased at altitudes above 1,000 feet to the corresponding values shown in Figs. 26 and 27.

5-Rating.—Airports not having landing areas meeting the minimum requirements for a 4-rating on size but which request rating, and which the Secretary of Commerce considers safe for the use to which they are being put, shall receive the rating of 5 on size of landing area.

0-Rating.—An airport which, in the opinion of the Secretary of Commerce, is unsafe for operation, but from which operations are nevertheless taking place and which requests a rating, will be rated 0 on size of effective landing area.

RATING ON NIGHT-LIGHTING EQUIPMENT

A-Rating.—Airports receiving an A-rating on night-lighting equipment shall have the following:

(a) *An Airport Beacon.*—The requirements for a satisfactory aeronautical beacon light for airports are adequate candlepower, not less than 100,000 for long range; proper distribution of light in the vertical plane to make the beacon visible all around the horizon and to the zenith, or nearly so, for altitudes of from 500 to 2,000 feet; distinctiveness for identification; flashes of not less than $\frac{1}{10}$ second duration; luminous period of not less than 10 per cent; and eclipse periods of not more than 10 seconds duration.

Apparatus having characteristics other than above specified but of equivalent effectiveness owing to greater luminous periods and shorter eclipse periods, greater candlepower, or color effect, may be used. In no case, however, shall the beam candlepower be less than 15,000 nor shall the luminous period be greater than 60 per cent. For beacons of 30,000 candlepower or less the luminous period shall be at least 35 per cent. Beacons of less than 20,000 candlepower shall have a distinctive color characteristic. All flashing beacons shall have a definite Morse code characteristic and shall be operated by flashing mechanisms so designed as not to interfere with radio reception.

The beacon may have fixed lenses, or a combination of lenses, with a flashing-light source; flash-panel lenses; neon lights, with or without optical apparatus, to the equivalent specified above; or it may be a rotating beacon, making 6 r.p.m., with at least one parabolic reflector not less than 24 inches in diameter, or other equivalent optical apparatus, and a light source of not less than one 1,000-watt, 110-volt lamp or one 900-watt, 30-volt lamp. In the case of beacons having a single light source and automatic lamp changer for bringing a spare lamp into the focal position shall be provided or else there shall be an auxiliary beacon of at least 10,000 candlepower which is either kept in operation with the major unit or so designed as to be turned on automatically without interruption of service.

Wherever practicable the airport beacon shall be installed directly on the airport or immediately adjacent thereto and in such manner as to be visible in all directions. In case the topography of the surrounding terrain is such as to necessitate installing the beacon at some distance from the airport, there shall be installed on the airport a green, flashing, double-light source auxiliary beacon of not less than 5,000 candlepower and with a definite Morse code characteristic, or in lieu thereof, a white, flashing, double-light source auxiliary beacon of not less than 10,000 candlepower and with a definite Morse code characteristic. In no case, however, shall the distance

from the main beacon to the nearest edge of the landing area of the airport exceed 1 mile.

(On the national airway system, flashing, red, course-lights are used at beacons where no landing fields are located, and flashing, yellow, course-lights are used at beacons where intermediate fields have been established. It is urgently recommended that green flashing, double-light source, auxiliary beacons of at least 5,000 candlepower and with definite Morse code characteristics be installed on the airports in addition to the major airport beacons. It is suggested that, where practicable, the auxiliary beacons be installed directly above the major beacons. The uniform use of red, yellow, and green auxiliary beacons to indicate landing conditions would add materially to the safety of night flying.)

(b) *An Illuminated Wind-direction Indicator.*—There shall be at least one illuminated wind-direction indicator, internally or externally lighted, equivalent in effect to the wind cone described under the requirements for an A-rating on general equipment and facilities. A lamp of not less than 200 watts with suitable reflector will be required for the internal lighting of this wind cone. For external lighting, a suitable system of lights and reflectors so mounted above the wind cone as to make it visible at night from a distance of 1,000 feet in any direction will be considered satisfactory.

(c) *Boundary Lights.*—The outline of the usable portion of the landing area shall be shown at night by boundary lights spaced not more than 300 feet apart and served by an underground distribution system. Either series or multiple circuits may be used.

The cable used for boundary-light circuits shall be insulated for at least the maximum open-circuit voltage obtainable on the circuit. The cable conductors shall be of copper, and for multiple circuits they shall be of such size that the voltage drop will not exceed 5 per cent of the normal operating voltage of the circuit, but in the case of neither series nor multiple circuits shall they be less than No. 8 B. & S. gage. In the case of multiple circuits using either a three-wire closed-ring circuit or a straight three-wire circuit, No. 10 B. & S. gage bare copper wire may be used for the third conductor. Such cable and wire shall be installed at a depth of at least 10 inches unless otherwise protected by suitable mechanical means.

For series circuits having normal operating voltages in excess of 310 volts, a series transformer (safety coil) shall be installed at the base of each boundary-light standard to prevent accident through high-tension current in event of collision with the light. In the case of series circuits with operating voltages of 310 or less, the use of such series transformers is not required, providing the maximum open-circuit voltage does not exceed 450 volts. A series circuit using two constant-current transformers with the secondary windings of these transformers connected in series and with both the point

of connection between these two secondary windings and a suitable point in the circuit effectively grounded, or other equivalent installation, may be used without the series transformers (safety coils) providing the operating voltage and the maximum open-circuit voltage at any part of the circuit do not exceed 310 and 450 volts, respectively. (A grounded circuit should not be installed without first finding whether it is in keeping with the practice of the power company supplying the current.)

Suitable weatherproof units with either plain or prismatic globes are required for the boundary lights. On all series circuits these units shall be provided with cutout sockets. In event of lamp failure such sockets are necessary to reestablish the circuit in the case of straight series circuits and in the case of series circuits with series transformers (safety coils), to short-circuit the series transformer secondary. (An open-circuited secondary sets up electromagnetic waves of such a frequency as to interfere with radio reception in the immediate vicinity.)

Either white or yellow lights shall be used in the boundary-light system, excepting as follows: Where the entire field is not available for landing in all directions at all times, green lights shall be so placed in the system as to indicate clearly the ranges of each landing strip or runway. Red lights shall be installed in the boundary system at points where an approach is particularly hazardous.

In multiple circuits, at least 25-watt lamps shall be used for white and yellow lights and at least 50-watt lamps for green and red lights. In the case of series circuits, S-24- $\frac{1}{2}$, 6.6-ampere, 600-lumen lamps shall be used for white and yellow lights, and 1,000-lumen lamps for green and red lights. Diffusing globes or frosted lamps shall be used for all white lights to prevent glare.

(d) *Obstruction Lights*.—All obstructions on and in the vicinity of the airport shall be clearly marked with red lights of the same wattage or lumen output as the red lights specified for the boundary circuit. Suitable weatherproof units shall be used and shall be mounted in each case above the highest point of the obstruction, or on poles of corresponding height placed alongside thereof. The use of a flashing mechanism in connection with the obstruction lights is not required or recommended; however, if such a mechanism is used it shall be so designed as not to interfere with radio reception in the vicinity.

In marking pole lines, an obstruction light shall be placed on each pole. (While not required by these regulations, it is very desirable from the standpoint of safety that two obstruction lights be placed on end poles and on corner poles; otherwise, the burning out of the single light in such locations may lead to serious results.) The lights marking such obstructions as a row of trees shall not be spaced more than 300 feet apart.

All tall isolated obstructions in the vicinity of the airport exceeding 100 feet in height, such as radio towers and masts, flag poles, transmission towers, water towers, chimneys, and other tall structures, shall be marked with at least two red lights placed directly above the obstruction, and with one red light, or more, as may be necessary to give visibility in all directions, placed at two-thirds the height and also at one-third the height of the obstruction. In lieu of such red obstruction lights, chimneys, water towers, and similar structures may be marked by adequate floodlighting.

(e) *Hangar Floodlights and Roof Marking.*—The exterior surface of each hangar on the airport shall be floodlighted to an average intensity of illumination of at least $2\frac{1}{2}$ foot-candles. This may be accomplished by a system of at least 200-watt lamps with industrial reflectors mounted about 10 feet above the surface and spaced on 20-foot centers in each direction on the roof and along the eaves and ends of the roof, or by the use of floodlight projectors giving this specified intensity of illumination. Such projectors shall be so installed as not to produce a glare that will interfere with planes using the airport. The hangar floodlighting equipment shall be lighted at times when night landings are being made.

The exterior surfaces of the hangars excepting roof areas used as the background for air markings, shall be of such a color as to reflect not less than 50 per cent of the light and at least one hangar roof, or other suitable area, shall be marked with the name of the city or town in the manner set forth on page 569. Said marking shall be so illuminated as to be visible from an altitude of at least 2,000 feet. (In case the marking is illuminated by exposed incandescent lamps or by neon tubes, the lamps or tubes should preferably be placed along the center line of the strokes of the lettering and other symbols and the roof should not be floodlighted. For outlining with incandescent lamps, not less than 10-watt sign lamps should be used and they should be spaced from 8 inches apart for 6-foot letters, to 12 inches apart for 12-foot letters or larger. Neon tubes should be either 11- or 15-millimeter by either 18- or 25-milliamperere red-neon tubing. If the illumination of the marking is by floodlighting, either industrial reflectors or floodlight projectors may be used, and the intensity of illumination should be at least 10 foot-candles and preferably 15 foot candles.)

(f) *A Ceiling Projector.*—For use as a ceiling projector there is required an incandescent searchlight with a parabolic reflector of not less than 12 inches in diameter and with at least a 250-watt lamp of the concentrated filament type used for spotlight or headlight service and a stray light shield giving a beam spread of not to exceed 7 degrees, or an equivalent apparatus. (Projectors limited to these minimum requirements will not necessarily be large enough to handle the needs of every airport. In some cases, depending upon local conditions, it may be necessary to use units up to 24 inches in

diameter and with 1,000-watt lamps.) The ceiling projector shall be mounted on a yoke with a quadrant or other suitable means for elevating and holding the light at the proper angle of elevation. In case the projector is used in such a manner as to necessitate the measuring of verticle angles, an inclinometer, transit, or theodolite shall be provided, or in lieu thereof, an alidade so graduated and installed as to give direct readings of the ceiling height.

(g) *Landing Area Floodlight System.*—This system, which may consist of one or more units, shall be such as to provide an even distribution of illumination (free from abrupt changes in intensity and from shadow areas over the entire usable portion of the landing area.) There shall be sufficient intensity of illumination to reveal the details of the surface and make depth perception readily possible from a minimum altitude of 30 feet in the center of the lighted area. The minimum vertical plane intensity of illumination over the usable portion of the landing area shall not be less than 0.15 foot-candle.

The floodlight system shall be immediately available for use through the operation of controls located at convenient points and shall be sufficiently elaborate or flexible to permit landing under all conditions of wind direction without the necessity of landing directly toward the light source.

There shall be sufficient light to illuminate objects and obstacles in the immediate vicinity of the airport in the direction of the beam and the floodlight unit or units shall be so designed and installed as to eliminate glare and blinding of the pilot.

Units shall be mounted as low as possible consistent with the contour of the landing area, shall project a beam of small vertical divergence with sharp cutoff at the top and with top of beam as nearly parallel with and as close to the surface of the landing area as practicable. When more than one unit is used each unit shall be separately fused or other suitable provision shall be made to prevent a short circuit in one unit from interrupting service of other units. In lighting areas of irregular, wavy contour, the units shall be so placed as to eliminate shadows.

Where the floodlighting is accomplished from a single light source, an automatic lamp changer shall be provided to bring a new lamp into the focal position in case of lamp failure. This lamp changer shall be so designed that the reserve lamp is ready to be placed immediately on the line. In lieu of a lamp changer an auxiliary unit may be provided which will give sufficient light for safe landing of aircraft should the major unit fail, and which will produce a minimum vertical plane intensity of illumination of not less than 0.035 foot-candle over the usable portion of the landing area. This auxiliary unit, if not in operation with the major unit, shall be so designed as to be turned on automatically without interruption of service and shall be located at or near the major unit in order to avoid confusion of the pilot due to sudden and unexpected change of location of the light source.

In case the landing area exceeds the size required for a Class 1-rating at the altitude in question, the area to be floodlighted in the manner hereinabove specified shall at least meet the size requirements for a Class 1-rating but need not exceed them. It is highly desirable, however, that the entire landing area be lighted.

(h) *All-night Operation of Lighting Equipment.*—The airport beacon, wind-direction indicator lights, boundary lights, obstruction lights, and roof-marking lights shall be kept burning all night (from sunset until sunrise) every night. (It is preferable that this equipment be kept burning from $\frac{1}{2}$ hour before sunset until $\frac{1}{2}$ hour after sunrise.)

(i) *Night Personnel.*—Sufficient personnel shall be in attendance throughout the night for proper operation of the lighting equipment, for servicing aircraft, making minor repairs and giving weather service, and for operating the fire-fighting equipment.

B-Rating.—Airports receiving a B-rating on night-lighting equipment shall have the following:

- (a) An airport beacon as required for an A-rating.
- (b) An illuminated wind-direction indicator as required for an A-rating.
- (c) Boundary lights as required for an A-rating.
- (d) Obstruction lights as required for an A-rating.
- (e) The exterior surface of one hangar floodlighted and the name of the city or town marked on a hangar roof, or other suitable area, and illuminated, all in the manner required for an A-rating.
- (f) A ceiling projector as required for an A-rating.
- (g) A landing-area floodlight system, portable or otherwise, which will provide suitable illumination for safe landing of airplanes under ordinary conditions and which will give a minimum vertical plane intensity of illumination over the usable portion of the landing area, or a portion thereof equivalent to the area required for a 1-rating on size, of at least 0.035 foot-candle.

(h) All-night operation of lighting equipment as required for an A-rating.

(i) Sufficient personnel in attendance throughout the night for proper operation of the lighting equipment, servicing aircraft, giving weather service, and operating fire-fighting equipment.

C-Rating.—Airports receiving a C-rating on night-lighting equipment shall have the following:

- (a) An airport beacon as required for an A-rating.
- (b) An illuminated wind-direction indicator as required for an A-rating, except that said wind-direction indicator shall be equivalent in effect to at least the wind-direction indicator required for a C-rating on general equipment and facilities.
- (c) Boundary lights as required for an A-rating.

- (d) Obstruction lights as required for an A-rating.
- (e) A ceiling projector as required for an A-rating.
- (f) The name of the city or town marked on a hangar roof, or other suitable area, and illuminated as required for an A-rating.
- (g) All-night operation of lighting equipment as required for an A-rating.
- (h) Attendance available on request.

D-Rating.—Airports not possessing sufficient night-lighting equipment to receive a C-rating but which possess either an airport beacon or boundary-light system, or both, together with an illuminated wind-direction indicator and adequate obstruction lights, will be given a rating of D, provided all such lighting equipment is kept burning all night every night.

E-Rating.—Airports having the necessary night-lighting equipment to meet the requirements of any of the above ratings and which keep this equipment available for operation on request, but which do not give the all-night operation required for these ratings, will be given the rating of E on night-lighting equipment.

X-Rating.—The rating of X will be given to airports having no night-lighting equipment, or which do not provide all-night operation of lighting equipment or which do not keep this equipment available for operation on request as hereinabove required.

BASIC REQUIREMENTS FOR RATING OF AIRPORTS FOR SEAPLANES

The minimum basic requirements for the rating of seaplane airports are as follows: The seaplane airport shall be situated on or directly connected with a body of water having a minimum depth of not less than 6 feet at any time, calm enough for operations in all ordinary weather, and sufficiently large to permit landing and taking-off of seaplanes and flying boats without hazard. By direct connection is meant a canal or other stream of water wide enough to allow taxiing of planes without difficulty and a distance of not over $\frac{1}{4}$ mile from the actual airport to the open water.

The airport shall be situated on a good road leading to the nearest city or town. It shall be equipped with an approved type of wind-direction indicator, as hereinabove specified, and shall be marked either on hangar roof, or other suitable area, or on land immediately adjacent to the water with the name of the city or town in the manner shown on page 552.

The airport shall be provided with facilities for supplying aircraft with fuel, oil, and water; also drinking water shall be available. If there are no restrooms on the airport a suitable latrine shall be provided. The airport shall have dependable communication and transportation facilities to the nearest city or town. Airport personnel shall be in attendance by day or available on call by telephone at the airport. In the latter case, a directory

and full instructions for reaching such personnel shall be available in the telephone booth or receptacle.

RATING ON GENERAL EQUIPMENT AND FACILITIES

A-Rating.—In addition to the facilities named in the basic requirements, seaplane airports rated A on general equipment shall have the following:

(a) At least one hangar measuring not less than 80 by 120 feet in the clear inside with doors open, with 22-foot overhead clearance, with full-width door opening in either one or both ends or one or both sides, and with safe provision for heating water and oil. In localities where freezing temperatures are experienced the hangar shall be heated sufficiently to prevent freezing of water.

(b) Wind-direction indicator as required for an A-rating for landplane airports.

(c) Day marking of telephone and transmission-line poles and similar obstructions in the immediate vicinity of the landing area as required for an A rating for landplane airports.

(d) Repair equipment sufficient to permit changing engines, pontoons, and amphibian landing gear in addition to equipment for major engine, plane, and hull repairs.

(e) Means for hauling planes out of the water. This will require either a marine railway or a suitable ramp. Dollies, cradles, or other apparatus suitable for carrying seaplanes and flying boats from the water into the hangar will be necessary, as well as power for hauling out cradles when loaded, such as a small tractor, a motor truck, or a winch.

(f) A boat capable of at least 10 knots speed for towing disabled planes to the airport and for use as a tender and rescue boat.

(g) Weather instruments as required for an A-rating for landplane airports.

(h) Radio-receiving set and loud speaker, under certain conditions, as required for an A-rating for landplane airports.

(i) First-aid equipment as required for an A-rating for landplane airports.

(j) Register as required for an A-rating for landplane airports.

(k) Mooring facilities properly placed offshore for flying boats or seaplanes.

(l) Adequate fire-fighting apparatus as required for an A-rating for landplane airports.

(m) Airport personnel as required for an A-rating for landplane airports.

(n) Sleeping quarters for at least three men, in addition to station personnel, as required for an A-rating for landplane airports.

(o) Waiting and restrooms at or near the hangar.

(p) Restaurant or other source of food supply as required for an A-rating for landplane airports.

B-Rating.—In addition to the facilities named in the basic requirements, seaplane airports rated B on general equipment shall have the following:

(a) At least one hangar measuring not less than 80 by 100 feet in the clear inside with doors open, with 18-foot overhead clearance, with full-width door opening in either one or both ends or one or both sides, and with safe provisions for heating water and oil.

(b) Wind-direction indicator as required for an A-rating for landplane airports.

(c) Day marking of telephone and transmission-line poles and similar obstructions in the immediate vicinity of the landing area as required for an A rating for landplane airports.

(d) Repair equipment sufficient to permit changing engines and pontoons and amphibian landing gear, in addition to equipment for minor engine, plane, and hull repairs.

(e) Means for hauling planes out of the water such as required for an A-rating for seaplane airports.

(f) A boat capable of at least 8 knots speed to act as tender, rescue boat, etc.

(g) Weather instruments as required for an A-rating for landplane airports.

(h) First-aid equipment as required for an A-rating for landplane airports.

(i) Register as required for an A-rating for landplane airports.

(j) Mooring facilities as required for an A-rating for seaplane airports.

(k) Adequate fire-fighting apparatus as required for an A-rating for landplane airports.

(l) Airport personnel as required for a B-rating for landplane airports.

(m) Sleeping quarters for at least two men, in addition to station personnel, as required for a B-rating for landplane airports.

(n) Restroom at or near hangar.

C-Rating.—In addition to the facilities named in the basic requirements, seaplane airports rated C on general equipment shall have the following:

(a) At least one hangar measuring not less than 50 by 60 feet in the clear inside with doors open, with 16-foot overhead clearance and with full-width door opening in either one or both ends or one or both sides, and with safe provisions for heating water and oil.

(b) Wind-direction indicator as required for a C-rating for landplane airports.

(c) Suitable means for hauling planes out of the water, such as required for an A-rating for seaplane airports.

(d) A boat capable of at least 8 knots speed for use as a tender, rescue boat, etc.

(e) First-aid equipment, fire-fighting equipment, and register as required for an A-rating for landplane airports. (The day marking of telephone

and transmission lines and similar obstructions in the immediate vicinity of the landing area as required for the A- and B-ratings is not required for either the C- or D-ratings, but is urgently recommended.)

(f) Restrooms.

D-Rating.—Seaplane airports which do not possess sufficient general equipment to obtain A-, B-, or C-ratings, but which meet the basic requirements, will receive a rating of D on general equipment and facilities.

RATING ON SIZE OF EFFECTIVE LANDING AREA

No seaplane airports will be rated unless they permit an unobstructed climb after taking-off. The existence of reefs, shoals, sandbars, etc., within the areas described hereafter as 1, 2, 3, or 4 will eliminate consideration for rating unless, in the opinion of the Department of Commerce, marking and lighting of these dangerous obstructions eliminate all hazard. Such markers will of course, have to conform to local and Federal harbor or river regulations both for day markers and night lights.

1-Rating.—In addition to the basic requirements, seaplane airports receiving 1 rating on size of effective landing area shall have clear approaches and be large enough to permit at least a 4,000 foot effective run in all directions.

2-Rating.—In addition to the basic requirements, seaplane airports receiving a 2-rating on size of effective landing area shall have clear approaches and shall be large enough to permit at least a 3,500-foot effective run in all directions or shall have two landing courses, one aligned with the general direction of the prevailing wind, with clear approaches and permitting at least four-way landing, the landing courses to be at least 600 feet wide and not less than 4,000 feet in effective length and not to cross or converge at an angle of less than 60 degrees.

3-Rating.—In addition to the basic requirements, seaplane airports receiving a 3-rating on size of effective landing area shall have clear approaches and shall be large enough to permit at least a 3,000-foot effective run in all directions, or shall have two landing courses, one aligned with the general direction of the prevailing wind, with clear approaches and permitting at least four-way landing, the landing courses to be at least 600 feet wide and not less than 3,500 feet in effective length and not to cross or converge at an angle of less than 60 degrees.

4-Rating.—A seaplane airport which meets the basic requirements but which is not large enough to receive a 3-rating on size of landing area will be rated as 4 if, in the opinion of the Secretary of Commerce, it provides sufficient area for the use to which it is being put.

0-Rating.—A seaplane airport which, in the opinion of the Secretary of Commerce, is unsafe for operation, but from which operations are never-

theless taking place and which requests a rating, will be rated 0 on size of effective landing area.

RATING ON NIGHT-LIGHTING EQUIPMENT

The matter of lighting seaplane airports is one to be treated as a separate problem in every case, as the possibility of interference with river, ocean, or harbor traffic makes general rules impossible. Floodlighting of the landing area is usually necessary, although the installation of boundary lights is ordinarily impracticable. Obstruction lights may be placed on obstacles if such lights do not conflict with local or Federal navigation laws and regulations. Lighting plans for seaplane airports shall be referred to the Department of Commerce, Washington, D. C., which department will determine whether there is any conflict between the proposed lighting system and the existing navigational aids for water craft, and whether the proposed system meets the special requirements for night lighting of such airports.

Subject to the foregoing statement, the requirements for the rating of seaplane airports on night-lighting equipment are as follows:

A-Rating.—Seaplane receiving an A-rating on night-lighting equipment shall have the following:

- (a) An airport beacon as required for an A-rating for landplane airports.
- (b) An illuminated wind-direction indicator as required for an A-rating for landplane airports.
- (c) Suitable boundary lights (when practicable).
- (d) Suitable obstruction lights.
- (e) The exterior surface of hangars floodlighted and the name of the city or town marked on a hangar roof, or other suitable surface, and illuminated, all as required for an A-rating for landplane airports.
- (f) Ceiling projector as required for an A-rating for landplane airports.
- (g) Landing area floodlight system as required for an A-rating for landplane airports.
- (h) All-night operation of lighting equipment as required for an A-rating for landplane airports.

(i) Night personnel as required for an A-rating for landplane airports.

B-Rating.—Seaplane airports receiving a B-rating on night-lighting equipment shall have the following:

- (a) An airport beacon as required for an A-rating for landplane airports.
- (b) An illuminated wind-direction indicator as required for an A-rating for landplane airports.
- (c) Suitable boundary lights (when practicable).
- (d) Suitable obstruction lights.

(e) The exterior surface of one hangar floodlighted and the name of the city or town marked on a hangar roof, or other suitable surface, and illuminated, all as required for an A-rating for landplane airports.

(f) A ceiling projector as required for an A-rating for landplane airports.

(g) A landing area floodlight system as required for a B-rating for landplane airports.

(h) All-night operation of lighting equipment as required for an A-rating for landplane airports.

(i) Night personnel as required for a B-rating for landplane airports.

C-Rating.—Seaplane airports receiving a C-rating on night-lighting equipment shall have the following:

(a) An airport beacon as required for an A-rating for landplane airports.

(b) An illuminated wind-direction indicator as required for a C-rating for landplane airports.

(c) Suitable boundary lights (when practicable).

(d) Suitable obstruction lights.

(e) Ceiling projector as required for an A-rating for landplane airports.

(f) The name of the city or town marked on a hangar roof, or other suitable surface, and illuminated as required for an A-rating for landplane airports.

(g) All-night operation of lighting equipment as required for an A-rating for landplane airports.

(h) Attendance available on request.

D-Rating.—Seaplane airports not possessing sufficient night-lighting equipment to receive a C-rating but which possess either an airport beacon or boundary-light system, or both, together with an illuminated wind-direction indicator and suitable obstruction lights, will be given a rating of D, providing all such lighting equipment is kept burning all night every night.

E-Rating.—Airports having the necessary night-lighting equipment to meet the requirements of any of the above ratings and which keep this equipment available for operation on request, but which do not give the all-night operation required for these ratings, will be given the rating of E on night-lighting equipment.

X-Rating.—The rating of X will be given all seaplane airports having no night-lighting equipment, or which do not provide all-night operation of lighting equipment or which do not keep this equipment available for operation on request as hereinabove required.

RATING ON COMBINED LANDPLANE AND SEAPLANE AIRPORTS

Airports offering facilities for the operation of both landplanes and seaplanes will be given two separate and distinct ratings, first as an airport for landplanes and second, as an airport for seaplanes.

SECTION XIV

AIR COMMERCE REGULATIONS

CHAPTER 1

LICENSING OF AIRCRAFT

Section 1. Licensing Law.

“ ‘Air commerce’ means transportation in whole or in part by aircraft of persons or property for hire, navigation of aircraft in furtherance of a business, or navigation of aircraft from one place to another for operation in the conduct of a business.” (Sec. 1, air commerce act of 1926.)

“ ‘Interstate or foreign air commerce’ means air commerce between any State, Territory, or possession, or the District of Columbia, and any place outside thereof; or between points within the same State, Territory, or possession, or the District of Columbia, but through the air space over any place outside thereof, or wholly within the air space over any Territory or possession, or the District of Columbia.” (Sec. 1.)

“The Secretary of Commerce shall, by regulation * * * provide for the granting of registration to aircraft eligible for registration, if the owner requests such registration * * *.” (Sec. 3 (a).)

“It shall be unlawful * * * to navigate any aircraft * * * in interstate or foreign air commerce unless such aircraft is registered as an air craft of the United States.” (Sec. 11 (a) (2).)

“To navigate any aircraft registered as an aircraft of the United States * * * without an aircraft certificate, or in violation of the terms of any such certificate.” (Sec. 11 (a) (3).)

“Any person who (1) violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of \$500 * * *.” (Sec. 11 (b).)

Aircraft means “any contrivance now known or hereafter invented, used, or designed for navigation of or flight in the air, except a parachute

or other contrivance designed for such navigation but used primarily as safety equipment." (Sec. 9 (c).)

Aircraft of the United States means "any aircraft registered" under the air commerce act. (Sec. 9 (f).)

Sec. 2. Application of the Law.

Aircraft must be licensed before engaging in—

(A) Carrying persons or property for hire, or the United States mails—

(1) Between two or more States, or to or from foreign countries, as from Chicago to Cleveland, Ohio, or from New York to Portland, Me., to Montreal, Canada.

(2) Between two points in one State if a part of the flight is over another State, as from Buffalo to New York via Susquehanna, Pa.; or from Buffalo, thence over any part of Pennsylvania, and thence back to Buffalo.

(3) Between two points in one State if it is a part of a through carriage between points in different States, or countries, as from Los Angeles to San Francisco, Calif., as a part of the carriage between Los Angeles and Seattle, Wash., or from San Antonio, Tex., to Laredo, Tex., as a part of the carriage between San Antonio and Monterey, Mexico.

(4) Within the air space over the District of Columbia, or any Territory or possession of the United States.

(B) Aircraft used solely for pleasure or noncommercial purposes need not be licensed, although engaged in flying between States, but, at the option of the owner, may be licensed, in which event it must observe all the requirements of licensed aircraft. Whether licensed or not, all aircraft must display the assigned identification mark.

Sec. 3. Aircraft Belonging to the United States.

Aircraft belonging to the United States will be licensed by the Secretary of Commerce if the operating agency so requests.

Sec. 4. Aircraft Belonging to States, etc.

Aircraft belonging to States, Territories, or possessions of the United States, or to political subdivisions thereof, will be licensed by the Secretary of Commerce and rated as to airworthiness in the same manner as other craft if request for licensing is made and such aircraft are used exclusively in the governmental service.

Sec. 5. Foreign Aircraft.

(A) Where civil aircraft of the United States are permitted to fly in or over a foreign country without registration and rating and licensing of their airmen, the aircraft of such foreign country, not a part of its armed forces, and the airmen serving in connection therewith, may operate without a license in the territory over which the United States has jurisdiction. Such foreign aircraft shall not engage in interstate or intrastate air commerce and must observe the air-traffic rules.

(B) Aircraft owned by resident aliens will be granted identification marks but shall not engage in interstate or intrastate air commerce.

(C) Registered aircraft of the United States shall not be flown or operated in air commerce in the United States or its possessions, by, or in behalf of any individual, partnership, firm, or corporation not eligible to license for such registered aircraft.

Sec. 6. Requisites of Licensing and Registration.

An aircraft, to be entitled to license and registry, must be airworthy and equipped in accordance with requirements of the Secretary of Commerce and owned by—

(A) A citizen of the United States and not registered under the laws of any foreign country; or

(B) A partnership of which each member is a citizen of the United States; or

(C) A corporation organized under the laws of the United States, a State, Territory, or possession of the United States, and of which the president and at least two-thirds of the directors or managing officers are citizens of the United States, and of which at least 51 per cent of the voting interest in the corporation is controlled by citizens of the United States; or

(D) The Government of the United States, a State, Territory, or possession, or a political subdivision thereof.

Sec. 7. Registration, Meaning of.

Registration means entry of licensed aircraft in an official license registry of the Secretary of Commerce as aircraft of the United States. Unlicensed aircraft, though entered of record for purposes of identification as required by law, are not registered aircraft within the meaning of these regulations.

Sec. 8. Airworthiness, Law of.

"The Secretary of Commerce shall by regulation * * * provide for the rating of aircraft of the United States as to their airworthiness * * *. The Secretary may, from time to time, rerate aircraft as to their airworthiness upon the basis of information obtained under this subdivision." (Sec. 3 (b).)

"It shall be unlawful * * * to navigate any aircraft registered as an aircraft of the United States without an aircraft certificate or in violation of the terms of any such certificate." (Sec. 11 (a) (3).)

"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of \$500." (Sec. 11 (b).)

Sec. 9. Airworthiness, Meaning of.

Airworthiness means a condition meeting the minimum aircraft requirements as set forth herein.

Sec. 10. Airworthiness Requirements.

(A) AIRWORTHINESS FACTORS.—In determining the airworthiness of airplanes the following factors are taken into consideration:

(1) The structural strength of wings, ailerons, tail surfaces, fuselage including engine mount, fittings, control system, and landing gear, as shown by stress analyses.

(2) Cockpit, cabin, and control arrangements.

(3) Power plant and power-plant installation.

(4) Equipment and instruments.

(5) Propellers.

(6) Design of fittings.

(7) Materials and workmanship.

(8) Flying characteristics and qualities.

Certain of these items may be demonstrated by theoretical analyses and drawings, others by visual inspection, and others by tests.

(B) LOAD-FACTOR REQUIREMENTS.—The load-factor requirements for the structural members of an airplane shall be determined as follows:

(1) *Flying Conditions*.—Figure 1 hereof, and hereby made a part of these regulations, shall be used to determine the load factors for the high angle of attack condition of landplanes and float-type seaplanes. Reference shall be made to it and the factor obtained for the appropriate weight and horsepower loading, the factors for gross weights which lie

between 2,500 and 12,500 pounds being determined by interpolation between the appropriate curves. For multi-engined airplanes the horsepower to be used for computing the loading in pounds per horsepower shall be that necessary to maintain level flight with full load at sea level. For flying boats and amphibians of 5,000 pounds gross weight or less the factor for 5,000 pounds shall be used; for gross weights in excess of 5,000 pounds the factors shall be those indicated by the actual weight and power loading.

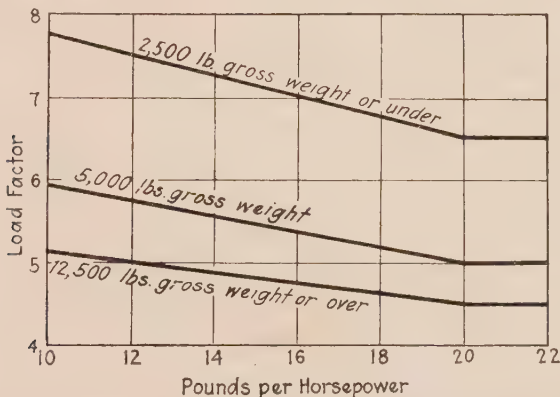


FIG. 1.—Load factors¹—high angle of attack. For flying boats and amphibians of 5,000 pounds gross weight or less, use the 5,000-pound gross weight factors. Horsepower loading shall be based on rated engine horsepower except that for multi-engined airplanes the horsepower shall be taken as that necessary to maintain level flight with full load.

In the low angle of attack condition the load factor shall be 65 per cent of the high angle of attack factor, but in no case less than 3.

For the inverted-flight and nose-dive conditions the load factor shall be 40 per cent of the high angle of attack factor, but in no case less than 2.

(2) *Landing Conditions.*—The load-factor requirements for landing conditions shall be obtained from Table 1. If the landing gear is designed to absorb landing shocks by the flow of a liquid through an

¹ It is to be noted that the load factors given in this chart are not sufficiently high to conform to the international requirements throughout the entire range of horsepower loading. Manufacturers designing airplanes for export should take into account the load factor and design requirements of the country to which the airplane is to be exported.

orifice (the oleo or oleo-pneumatic type), the design load factors for the landing gear may be reduced by not more than 25 per cent from those shown in Table 1, but suitable provision shall be made to carry taxiing shocks after the absorber has been forced to the full extent of its travel.

For float seaplanes the floats and the members to which they are attached, including the "carry-through" tubes in the fuselage, shall be designed for a factor in landing of 8.0.

The shock absorber in the chassis of a landplane or amphibian shall be designed to absorb the energy generated by a free drop of the airplane from the height specified in Table 1 without subjecting the airplane or landing gear to forces greater than those corresponding to the load factors for landing.

The tail-skid shock absorber shall be designed to resist a free drop in the three-point landing attitude equal to that shown in Table 1 without imposing loads on the tail skid or fuselage greater than those corresponding to the load factors for landing.

(3) *Tail Surfaces and Ailerons*.—Tail surfaces and ailerons shall be designed to withstand the loads specified in Table 1.

TABLE 1

Class	Factor for landing conditions	Height of free drop for design of shock absorber (inches)	Loads per square foot on ailerons and horizontal tail surfaces	Vertical tail surfaces
2,500-pound or less...	6.5	24	30	} 75 per cent of load required on horizontal surfaces.
5,000-pound.....	5.5	22	25	
12,500-pound.....	5.0	20	20	
12,500-pound or over.	4.5	18	20	

(4) *Seaplane Floats and Boat Hulls*.—Flying-boat and seaplane float bottoms shall be designed to withstand, without permanent set, the following loads:

(a) Eight pounds per square inch over that portion of the hull lying between the first step and a section 25 per cent of the distance from the step to the bow; (b) 4 pounds per square inch from that section to a section at 75 per cent of the distance from the step to the bow; (c) 4 pounds per square inch between the first and second steps; and (d) 4

pounds per square inch between the rear step and a section 50 per cent of the distance to the stern. If but one step is used, this load shall extend over that portion of the hull between the step and a section 50 per cent of the distance from the step to the stern.

The submerged displacement of the main floats shall be at least 190 per cent of the full load of the airplane. Main floats shall be divided into at least five water-tight compartments.

In designing the bow portion of the hull due attention must be paid to the effect of striking floating objects.

(C) CONTROL SYSTEM.—The control system shall be designed to withstand a load of at least 300 pounds in a fore-and-aft direction and 150 pounds in a lateral direction applied at the grip on a stick control; on a wheel control it shall withstand at least 300 pounds in a fore-and-aft direction applied at the center of the wheel and a couple equal to 125 pounds times the diameter of the wheel applied tangent to the rim of the wheel. The rudder controls shall be designed to withstand a load of not less than 300 pounds applied at the point of contact with the foot. On airplanes having a gross weight of 1,000 pounds or less, two-thirds of the above values may be used. In any case, the strength of the control system shall be sufficient to withstand loads on the control surfaces 25 per cent greater than those specified in Table 1 for the design of the surfaces. The entire control system shall be so designed that the rudder, elevators, ailerons, and other movable parts thereof will not jam, and, if necessary, control stops shall be provided to prevent it.

Dual controls on airplanes carrying passengers for hire shall be so constructed or arranged as to prevent passengers from interfering with the course of flight of the airplane.

(D) CONSTRUCTION OF COCKPIT AND CABIN.—The cockpit or cabin shall be constructed to afford suitable ventilation, adequate vision to pilot under normal flying requirements, and reasonable protection to pilot and passengers against possible propeller breakage.

Closed cabins of airplanes carrying passengers for hire shall have not less than two exits, affording maximum ease of operation. One of such exits may be an emergency exit, in which case the size, location, and method of operation shall be subject to the approval of the Secretary of Commerce.

(E) POWER-PLANT REQUIREMENTS.—Engines which have passed the regular endurance tests of the United States Army Air Corps or the

United States Navy Bureau of Aeronautics will be approved by the Department of Commerce. Other engines submitted for approval will be tested by the Department of Commerce at the Bureau of Standards.

The log shall include the following:

Piston displacement, compression ratio, type of ignition, carbureter and spark plugs; barometric reading and complete list of instruments and apparatus used for the test. The length of brake arm and gear ratio if propeller is geared shall also be given. The test shall be such as to develop the following data:

(1) A plot of power developed at various revolutions per minute with the throttle wide open.

(2) Record of log showing readings, at approximately 30-minute intervals, of—

- (a) Revolutions per minute.
- (b) Brake load in pounds.
- (c) Oil pressure and temperatures.
- (d) Water temperatures.
- (e) Air temperature at carbureter intake.
- (f) Blast velocity.
- (g) Maximum cylinder temperature, head and barrel.
- (h) Manifold depression in inches of mercury.
- (i) Fuel time in seconds for at least 5 pounds.
- (j) Oil in pounds.
- (k) Brake horsepower.
- (l) Remarks, including breakages and replacements.

The 50-hour endurance test shall be run in 10 five-hour periods. During the first 5 hours the engine shall be run with the throttle wide open, the speed being at least equal to the rated speed and the power being at least 10 per cent in excess of the rated power. During the remaining 45 hours the engine shall be run at approximately rated speed and the horsepower developed should at no time be less than the rated horsepower.

(3) Photographs showing set-up of the testing apparatus used and of any parts which failed or showed excessive wear.

(4) List of instruments and apparatus used.

(5) After completion of the test, and a complete tear down, a report of detailed inspection of engine parts, particular attention to be paid to excessive wear and signs of failure.

An engine, after successfully passing the required block tests, shall be installed in an airplane and given actual service tests.

A newly constructed engine of a type and design which has been tested in accordance with the provisions hereof must not be installed in an airplane until bench tested for at least two hours, during at least one-half hour of which the engine must be run at full throttle.

An engine which has been in storage for more than one year must not be installed in an airplane until it has been reconditioned in accordance with accepted safety practices.

A reconditioned engine must be run for at least 20 minutes at full throttle before it shall be used in propelling registered aircraft carrying persons or property for hire.

(F) POWER-PLANT INSTALLATION.—With water-cooled engine installation a fire wall of terneplate, galvanized steel, asbestos-aluminum combination, or equivalent thereof, shall be installed, insulating the engine section from other parts of the airplane. Aluminum or aluminum-alloy fire walls will be satisfactory for air-cooled engine installations. Openings made in the fire wall to allow the passage of pipes or wires shall be provided with suitable glands or gaskets.

Carbureter air intakes must open outside the cowling and shall be suitably drained. Exhaust manifolds shall be installed outside of cowling unless specifically authorized by the Secretary of Commerce.

Throttle-control and ignition switches on multi-engined airplanes shall be arranged to permit separate and simultaneous control.

Suitable ventilation shall be provided for the engine compartments.

Air-pressure gasoline-feed systems shall not be used without approval of the department.

Airplanes carrying passengers for hire shall have installed an adequate reserve-gasoline supply tank, or satisfactory, reliable apparatus for indicating to the pilot a depletion of the gasoline supply.

(G) PROPELLERS.—Propellers which satisfy any of the following requirements will be acceptable.

(1) Designs from which a propeller has been flown for 150 hours without failure on an engine of equal or greater power than that for which the approved rating is sought. Affidavit specifying the number of hours of satisfactory service on a given engine and aircraft, the name of the operator, operating firm, and other pertinent data shall

be forwarded to the Secretary of Commerce, together with detailed drawings of the propeller.

(2) Designs which embody only minor modifications from propellers accepted and used by the United States Army or Navy, the contractor to state specifically the departure, if any, from Government design.

(3) Designs which are approved designs, cut down to smaller diameters without reduction of the maximum ordinates, except in the immediate neighborhood of the tip.

Propellers not in accordance with the foregoing shall be tested in the manner prescribed by the Secretary of Commerce.

Propellers must have a ground clearance of at least 6 inches when the airplane is in a horizontal position.

On multi-engined airplanes a clearance of at least 1 inch must be provided between the tips of the propellers and the fuselage or any part of the structure.

The seats shall be so arranged that pilots and passengers are more than 12 inches forward or aft of the propeller disks. Surfaces near the propeller tips must be suitably stiffened against vibration.

(H) PERFORMANCE REQUIREMENTS.—(1) The following flight tests with the design gross load shall be required:

(a) General flight, which includes a half-hour flight test with full load, to determine stability.

(b) General maneuverability, which includes, among other things, a flight with full load around two pylons or buoys 1,500 feet apart, making five successive figure 8's at 1,000 feet without varying more than 200 feet in height in a radius not to exceed the following:

Five hundred feet for airplanes of full load not in excess of 5,000 pounds.

Seven hundred and fifty feet for airplanes of full load over 5,000 pounds and not in excess of 12,500 pounds.

One thousand feet for all other airplanes.

(2) The landing speed shall not exceed 60 miles per hour when the airplane is provided with a braking device, or 50 miles per hour when not so provided. Landing speed may be assumed equal to the calculated stalling speed. If the foregoing landing speeds are exceeded the following flight tests with full load shall be required:

(a) Take-off within 1,500 feet.

(b) Climb at least 250 feet the first minute after taking off.

(c) Land, coming to a full stop without external aid, within 1,000 feet from the point where the landing gear first touches the landing area.

(3) Tests are to be calculated upon the basis of air of a specific weight of 0.07635 and still-air conditions.

(4) The applicant must provide the person to make the flight tests, but an inspector from the Department of Commerce may pilot the airplane during such parts of the test as may be deemed necessary.

(5) No persons other than the crew necessary to conduct the flight shall be carried during performance tests. Sand or similar ballast shall be carried as a substitute for the passengers or cargo ordinarily carried as pay load.

(I) **EQUIPMENT AND INSTRUMENT REQUIREMENTS.**—The equipment and instruments required, which must be serviceable and in operating condition are:

(1) *Equipment.*—(a) Fire-extinguishing equipment, of design approved by the Secretary of Commerce. Cabin airplanes carrying passengers for hire must be equipped with at least one portable extinguisher accessible to the passengers.

(b) First-aid kits on airplanes carrying passengers for hire.

(c) Safety belts or equivalent apparatus for pilots and passengers in open-cockpit airplanes carrying passengers for hire. Seats or chairs in cabin planes shall be firmly secured in place.

(d) Electrical equipment and installation must be approved by the Secretary of Commerce.

(2) *Instruments.*—(a) Tachometer for each engine.

(b) Oil-pressure gauge where oil-pressure systems are employed.

(c) Water thermometer for water-cooled engines and oil thermometer for air-cooled engines.

(d) Altimeter.

(3) *Compass Requirements.*—An airplane flying cross country 100 or more miles and an airplane, including a seaplane, operating over large bodies of water beyond the sight of land must be equipped with a compass.

(J) **MANUFACTURER'S IDENTIFICATION DATA.**—(1) The date of manufacture or date of remodeling and the name of the manufacturer or remodeler, together with the manufacturer's serial number and type of engine, must be permanently affixed in a visible location by

means of a metal plate in the pilot's cockpit or compartment, of each airplane, in order that it may be distinguished from all other aircraft.

(2) The following specifications shall be stenciled or otherwise displayed on the outside of the fuselage or cabin at a point adjacent to the entrance into the cockpit or cabin in such manner as to be readily visible to persons proposing to enter the same: Over-all span; over-all length; weight empty; useful load; gross weight; seating capacity, exclusive of crew; gasoline capacity; oil capacity.

(3) Upon airplanes manufactured under an approved type certificate the manufacturer thereof may display the insignia shown herewith, in conjunction with the above data required to be stenciled on the airplane.

DOE AIRCRAFT MFG. CO., INC.		
		
Overall span.....	Ft.	In.
Overall length.....	Ft.	In.
Weight empty.....	Lbs.	
Useful load.....	Lbs.	
Gross weight.....	Lbs.	
Seating capacity exclusive of crew.....	Persons	
Gasoline capacity.....	Gals.	
Oil capacity.....	Gals.	

FIG. 2.—Typical stencil for airplanes.

The insignia, if used, shall be 16 inches in width and 3 inches in height and shall be identical with that shown except that the name of the manufacturer shall appear above it in the manner indicated, and the number of the approved type certificate under which the identical airplane was manufactured shall appear in the circle thereof. The stenciled data shall appear under it in the manner and proportion shown. This insignia shall only be used on airplanes for which application for license has been made, or for which license has been issued, and must be obliterated in the event the airplane is subsequently disapproved for license. Such a stencil is shown in Fig. 2.

Sec. 11. Approved Type Certificate, Requirements for.

(A) APPLICATION.—A manufacturer of airplanes, engines, or propellers in quantities and of an exact similarity of type, structure,

materials, assembly, and workmanship may, at the option of the manufacturer, file with the Secretary of Commerce an application under oath for an approved type certificate accompanied by the data specified, in duplicate. The design or test data must bear the signature of the responsible engineer.

(B) AIRPLANES.—In order to represent the structure of an airplane satisfactorily the data submitted shall include—

(1) A general assembly drawing of each wing, with the sizes and locations of spars, drag struts, drag wires, leading edge, trailing edge, and members supporting the ailerons and controls clearly indicated.

(2) Drawings of a typical rib, showing method of attachment to the spars and leading edge.

(3) Line diagrams of the external wing bracing, showing truss dimensions, sizes of struts, and wires.

(4) Layout of the fuselage structure, showing sizes of all members of the primary structure.

(5) Drawings of the tail surfaces, showing sizes of spars, torque tubes, internal and external braces, location of hinges, and masts.

(6) Chassis drawings giving a layout of the landing gear that shows sizes of struts, axle, bracing wires, shock-absorber spindles, spreader tubes, and other important members and the method of connecting them. Drawings of the tail skid, showing the skid, its connection to the main fuselage structure, and the method of steering it, if any.

(7) For seaplanes, drawings of the floats, showing their lines, general dimensions, and a layout showing sizes of struts and wires and method of attachment to the fuselage.

(8) Detail drawings of the mechanisms used to adjust the stabilizer, fin, wing flaps, or similar surfaces while in flight.

(9) Drawings showing the main wing fittings and the control system are required. The analyses must cover the investigation of the strength of the main members of the wings, tail surfaces, landing gear, including tail skids, fuselage, fittings, and control systems for the load factors required in section 10. The analysis of secondary members carrying heavy loads and the investigation of main members subjected to eccentric loads are required.

(10) Stress analysis of the control surfaces and control systems may be supplanted by tests made on these units, assembled as in flight, if the tests show that the unit will carry 125 per cent of the design load,

and if the stick, rudder bar, etc., withstand the loads specified in section 10 (C).

(11) The stress analysis shall state the material used for members, whether or not it is heat-treated, and what physical properties are guaranteed, not assumed, by the manufacturer. If metal members of special design are used, test data showing their strength properties under loads similar to those to which they will be subjected in the structure must be submitted.

(C) ENGINES.—Data on engines, showing that the requirements of section 10 (E) and (F) have been complied with, and a complete set of drawings, must be submitted in duplicate by the engine manufacturer when applying for an approved type certificate.

(D) PROPELLERS.—Data on propellers, specified in section 10 (G), and a complete set of drawings must be submitted in duplicate by the propeller manufacturer when applying for an approved type certificate.

(E) INSPECTION AND FLIGHT TESTS OF AIRPLANES.—If the submitted design is approved and the aircraft meets the requirements stated herein, it will be inspected for exact similarity with the submitted design and specifications. Upon passing such inspection, the airplane must undergo the flight tests prescribed in section 10 (H). If such tests are passed, an approved type certificate will be issued to the manufacturer.

(F) CONSTRUCTION UNDER APPROVED TYPE CERTIFICATE.—The approved type certificate will be issued upon the condition that each quarter the manufacturer will file his affidavit with the Secretary of Commerce, showing the number of airplanes, engines, or propellers constructed under the approved type certificate during the quarter, with a statement that no airplane, engine, or propeller is being constructed, under such certificate, deviating from the terms thereof.

(G) CHANGES.—Changes in airplanes constructed under an approved type certificate are permissible, with the approval of the Secretary of Commerce.

(H) MANUFACTURER'S AFFIDAVIT.—Upon the sale by the manufacturer of airplanes of an exact similarity of type, structure, materials, assembly, and workmanship with the specimen for which the approved type certificate is issued, the manufacturer may deliver to the purchaser a manufacturer's affidavit, copies of which will be furnished the manufacturer upon request.

Sec. 12. Application for Aircraft License.

Before an aircraft license will be issued, the owner must file, under oath, with the Secretary of Commerce, an application for the license upon blanks provided by the Secretary of Commerce. Copies thereof will be forwarded upon request.

Sec. 13. Licensing and Expediting the Licensing of Approved Type Airplanes.

(A) For the purpose of expediting the licensing of airplanes constructed under approved type certificates and in the original possession of the manufacturer or dealer, the following provisions may be invoked, at the option of the manufacturer or dealer. The manufacturer or dealer may present the manufacturer's affidavit showing that the aircraft is exactly similar to the specimen of the approved type and have the airplane flight tested. If the flight tests prescribed in section 10 are passed and the aircraft inspector finds that the airplane is exactly similar to the specimen, a flight certificate will be issued for such airplane, good for 90 days after date and renewable for 90-day periods upon findings of the Secretary of Commerce that the airplane is in substantially the same condition as when the original certificate was issued. The manufacturer's affidavit and the flight certificate may be delivered to any purchaser and will be given such effect as is provided therefor in paragraph (B) of this section.

(B) An airplane constructed under an approved type certificate and in the possession of and owned by an eligible owner of aircraft of the United States will be licensed as follows:

(1) If the application is accompanied by the manufacturer's affidavit, the airplane will be inspected for similarity to the specimen and will be given the flight tests prescribed in section 10. If such inspections and tests are passed and the airplane is found to be equipped as required by these regulations, it will be licensed.

(2) If the application is accompanied by both the manufacturer's affidavit and a valid flight certificate, it will be licensed if found to be equipped as required by these regulations.

(3) If the application is not accompanied by the manufacturer's affidavit and the flight certificate, it will be licensed under the provision of section 14 hereof.

Sec. 14. Licensing of Airplanes not Constructed under Approved Type Certificates.

(A) For an airplane constructed after October 1, 1927, and not manufactured under approved type certificate, the application for the license must be accompanied by the information specified in the requirements for approved type certificate.

(B) *Tests.*—(1) For an airplane constructed after October 1, 1927, in conformity to the airworthiness requirements of these regulations and which passes the flight tests specified in section 10, an aircraft license will be issued by the Secretary of Commerce.

(2) For airplanes constructed prior to October 1, 1927, and found by the Secretary of Commerce to be of proper design, assembly, and workmanship, and of suitable materials and equipped in accordance with these regulations, aircraft licenses will be issued after such airplanes have passed the flight tests specified in section 10.

Sec. 15. Licensing of Special Classes of Airplanes.

Racing and experimental airplanes and airplanes of unusual design will be granted special aircraft licenses, and other aircraft may be specially licensed for other purposes and shall be operated only in accordance with the conditions specified in such licenses.

Sec. 16. Places for Airworthiness Tests.

The Secretary of Commerce will fix the time and place for all inspections and tests for airworthiness.

Sec. 17. Licenses—Contents.

Aircraft licenses will be issued for a period of not exceeding one year and will identify the airplane, specify the authorized type of the engine and the authorized gross weight, and will be granted subject to compliance with these regulations.

Sec. 18. Sale of Licensed Aircraft.

On the date of sale or transfer of title of licensed aircraft the vendor shall report in writing to the Secretary of Commerce the date and place of sale or transfer, and the name and residence of the vendee, and on said date return to the Secretary of Commerce the aircraft license and the metal plate furnished by the Secretary of Commerce.

If the sale is to an ineligible owner of aircraft of the United States, the aircraft license terminates as of the date of such sale. If the vendee is an eligible owner, he is responsible for filing with the Secretary of Commerce a properly executed purchaser's renewable application, if such vendee desires to have the aircraft licensed in his name for the unexpired term of said license. In the event the vendee does not elect to have the aircraft relicensed or is not an eligible owner, application, in duplicate, for identification mark shall be made to the Secretary of Commerce. In such case the vendee shall cause to be removed or obliterated from the aircraft the letter or letters which precede the license numeral or numerals.

The vendee, if an eligible owner of licensed aircraft, may, under the license number already assigned, operate the aircraft for a period of 20 days from the date of mailing the application or delivering the same in person to the Secretary of Commerce. In no case shall this period extend beyond 30 days from the date of sale. In all cases the vendee must attach to his application the bill of sale or a certified copy thereof.

Between the date of sale and the posting in the mails or delivery in person to an authorized representative of the Secretary of Commerce of the purchaser's renewable application or application for identification mark the aircraft is considered unlicensed and unidentified, and the operation thereof constitutes a violation of these regulations.

Sec. 19. Relicensing of Aircraft.

Upon the expiration of the term of an existing aircraft license the aircraft will be relicensed for additional periods of not exceeding one year upon the application of the licensed owner for relicensing and the finding of the Secretary of Commerce that the aircraft is airworthy and is owned by an eligible owner.

Sec. 20. Display and Surrender of License.

The aircraft license must be carried in the aircraft whenever it is in service and must be conspicuously posted where it may be readily seen by passengers or inspectors. Whenever the craft is unairworthy the license must be removed from the craft, and when the license is suspended or revoked, or when it is no longer in force, it shall be surrendered to the Secretary of Commerce. The license must be

presented for inspection upon the demand of any passenger or of any authorized official or employee of the Department of Commerce or State or municipal officials charged with enforcing local regulations or laws involving Federal compliance.

Sec. 21. Licensing of Airships and Balloons.

Until otherwise provided by regulations, the licensing of airships and balloons shall be in accordance with special orders of the Secretary of Commerce.

Sec. 22. Meaning of Airplane.

Except as otherwise specifically shown, the word "airplane" as used in this chapter includes seaplane, or any combination of landplane, seaplane, or boat.

Sec. 23. Canceling Licenses upon Request.

Upon the request of the licensed owner the aircraft license will be canceled by the Secretary of Commerce.

Sec. 24. Revocation and Suspension of Licenses—Law.

"The Secretary of Commerce shall by regulation * * * provide for the * * * suspension and revocation of registration (and) aircraft certificates." (Sec. 3 (f).)

Sec. 25. Ground for Revocation or Suspension.

Aircraft licenses will be suspended or revoked for—

(A) Violating the air commerce act or any of these regulations.

(B) Failing to make proper and seasonable reports.

(C) Making false statement in application or information accompanying the application for the license, or in any report required under these regulations.

(D) Equipping the airplane with a type of engine not specified in the license or approved by the Secretary of Commerce.

(E) Remodeling the engine and using it to propel licensed aircraft without the aircraft having been first rerated as airworthy by the Secretary of Commerce.

(F) Remodeling the airplane structure and flying the airplane without having it first rerated as airworthy by the Secretary of Commerce.

(G) Operating the airplane in excess of the authorized useful load specified in the license.

(H) Operating with passengers in excess of the original designed seating arrangement. Infants under 2 years of age are excepted, provided the maximum allowable useful load is not exceeded.

(I) Using or displaying license for fraudulent purposes.

(J) Using or displaying license in any manner contrary to the public safety or interest.

CHAPTER 2

INSPECTION OF AIRCRAFT

Sec. 26. Continuous Duty as to Flying Condition.

After an aircraft is licensed, and between the times that it is inspected for airworthiness by an inspector, the owner is charged with the continuous duty of maintaining the aircraft in a good and proper state of repair and flying condition. For violation of this duty or of the inspections required in the next succeeding section the aircraft license will be suspended or revoked.

Sec. 27. Daily and Periodic Inspections.

(A) A licensed airplane shall be given a line inspection by the owner or a licensed mechanic at least once within each 24 hours preceding flight, and the result thereof shall be entered in the log under the signature of the person making such inspection. The line inspection must be made to ascertain the working condition and state of repair of the—

(1) Open control wires, all control wires and pulleys open to inspection through apertures, and all hinges on control surfaces.

(2) Landing gear, wheels, fittings, and shock absorbers.

(3) Fuselage parts open to visual inspection.

(4) Main plane external bracing, including fittings and struts, external wires, cables, turnbuckles, and fabric or covering.

(5) Control surface fabric or covering.

(6) Engine-exhaust manifolds and exhaust-pipe extensions. The engine shall be given a warming-up test, during which the proper functioning of the engine instruments shall be ascertained.

(7) Carbureters and fuel-feed lines open to visual inspection to insure proper functioning.

(8) Cooling system and connections.

(9) Cowling, to insure that the cowlings are properly secured and safetied.

(10) Propellers, as to condition.

(B) After each 100 hours of flight, in addition to the line inspection, the airplane must be given a "periodic inspection" by the owner, and the result thereof must be entered in the log by the person making such inspection. This inspection must be made to ascertain the working condition and state of repair of the—

(1) Engine installation.

(2) Control systems throughout.

(3) Propeller alignment.

(4) Fuselage, including fittings, tail skid, and tail-skid shock absorbers.

Sec. 28. Government Inspections.

The inspector or other authorized officer of the Secretary of Commerce shall be permitted by the owner or operator to inspect the licensed aircraft at any time and place for the purpose of determining its flying condition and state of repair. For such purposes the owner or operator shall give to such inspector or officer free and uninterrupted access to the aircraft and the field or shelter where the craft is located.

CHAPTER 3

OPERATION OF AIRCRAFT

Sec. 29. Solo Flights with Passenger Planes.

In addition to the requirements of section 10 (E), licensed airplanes with newly installed engines, old, new, or reconditioned, and airplanes upon which major repairs have been made to the plane structure, must be first test flown by a licensed pilot without passengers for hire.

Sec. 30. Carrying Passengers at Night.

Licensed aircraft, when engaged in carrying passengers for hire any time between one-half hour after sunset and one-half hour before sunrise, must be equipped with electric landing lights and navigation lights.

Sec. 31. Supplies and Equipment for Flights over Water.

An airplane flying over large bodies of water must be provided with an adequate supply of food and potable water, and, if engaged in carrying passengers for hire, it must be equipped with a Very's pistol or approved equivalent and life preservers or other flotation devices approved by the Secretary of Commerce.

Sec. 32. Repairs after Accident Reports.

After repairs have been made on a licensed aircraft which has been seriously damaged, the license owner shall make full report to the Secretary of Commerce of the kind and extent of repairs made to the craft.

Sec. 33. Flying Seriously Damaged Airplanes.

A licensed airplane which is seriously damaged must not be flown with passengers for hire until it has been fully repaired and its flying condition approved by an inspector.

Sec. 34. Accident Reports.

Where serious injury to person or property is suffered or death results in operating licensed aircraft, the owner of such aircraft shall immediately report, by telegraph or telephone, to the Secretary of Commerce, the license number or identification number of the aircraft and the time and place of the accident. All accidents in the operation of licensed aircraft which result in injury to the aircraft shall be reported without delay on the form provided for that purpose.

Sec. 35. Logs and Navigation Reports.

The owner or operator of every licensed aircraft shall keep a navigation and engine log book and shall quarterly transmit to the Secretary of Commerce a navigation summary report, in duplicate, showing the number of hours and the approximate number of miles the aircraft has been flown during the quarter, the duration of the use of each engine, the engine installation and repairs, and the plane structure and rigging changes and repairs.

The log books shall be carried in the aircraft at all times when such aircraft is away from its home airport.

Sec. 36. Foreign Air Commerce.

Until otherwise provided, the laws of the United States and regulations made thereunder with respect to the entry and clearance of vessels engaged in foreign commerce are hereby made applicable to aircraft engaged in foreign air commerce.

CHAPTER 4**MARKING OF LICENSED AND UNLICENSED AIRCRAFT****Sec. 37. Marking of Aircraft, Law of.**

"The Secretary of Commerce shall by regulation * * * establish air traffic rules for the * * * identification of aircraft * * *." (Sec. 3 (e).)

Sec. 38. Identification Marks for Government and Special Classes of Aircraft.

(A) For aircraft belonging to the Government of the United States identification marks or symbols will be assigned in accordance with arrangements to be made with the affected departments.

(B) Licensed airplanes engaged in racing or experimental work, or specially licensed for other purposes, will be assigned special identification numbers or symbols.

Sec. 39. Identification Marks for Licensed Aircraft.

A licensed aircraft shall bear an identification mark consisting of the license number of the aircraft preceded by—

The Roman capital letter S (meaning State) for aircraft used solely for governmental purposes and belonging to States, Territories, possessions, or political subdivisions thereof, and

The Roman capital letter C for all other licensed aircraft.

Aircraft not licensed, but eligible and for which application for license has been filed with the Secretary of Commerce, will be assigned only a temporary number pending the issuance of license.

The letter N must precede the license symbol and numerals on licensed aircraft engaged in foreign air commerce and, at the option of the owner, may precede it on other licensed aircraft. *The identifica-*

tion mark will be assigned to licensed aircraft when the aircraft license is issued, and a separate application is not required.

Sec. 40. Identification Marks for Unlicensed Aircraft.

(A) Unlicensed aircraft must display, when in flight, an identification mark assigned by the Secretary of Commerce. The mark will be assigned upon the application of the aircraft owner and must be permanently affixed to the aircraft. It will consist of a number only. The nationality mark shall not be made a part of it, nor shall any other letter, design, symbol, or description be added thereto.

(B) On the date of sale or transfer of title of unlicensed identified aircraft the vendor shall report in writing to the Secretary of Commerce, advising the date and place of sale or transfer, and the name and residence of the vendee, and on said date shall return to the Secretary of Commerce the metal plate furnished by the Secretary of Commerce and the identification-mark assignment issued for such aircraft.

(C) Upon such sale the identification mark may be reassigned to the vendee, provided he files an original application for identification mark, in duplicate, with the Secretary of Commerce, requesting such reassignment and attaches to the application the bill of sale or a certified copy thereof.

(D) The vendee may operate such aircraft under the identification mark already assigned for a period of 20 days from the date of filing the application. In no event shall such period extend beyond 30 days from the date of sale.

(E) Between the date of sale and date of posting in the mails or delivery in person to an authorized representative of the Secretary of Commerce of the new application the aircraft is considered unidentified, and its operation will constitute a violation of these regulations.

Sec. 41. Places and Dimensions of Marks.

Identification marks shall be located as follows:

(A) ON AIRPLANES.—On the lower surface of the lower left wing and the upper surface of the upper right wing, the top of the letters or figures to be toward the leading edge, the height to be at least four-fifths of the mean chord; provided, however, that in the event four-fifths of the mean chord is more than 30 inches, the height of the letters and figures need not be more but shall not be less than 30 inches. If

the lower left plane is less than one-half the span of the upper left plane, the letters or figures thus described shall be on the under surface of the upper left plane, as far to the left as is possible. In the case of a monoplane the mark shall be displayed on the lower surface of the left wing and the upper surface of the right wing in the manner thus described. The marks shall also appear on both sides of the rudder, of size as large as the surface will permit, leaving a margin of at least 2 inches.

(B) ON AIRSHIPS.—On both sides near the maximum cross section and on the lower under surface of the nose, the height to be equal to at least one-twelfth of the circumference at the maximum transverse cross section of the airship, but it need not exceed 8 feet.

(C) ON BALLOONS.—Twice, near the maximum horizontal circumference, as far as possible from one another, the height to be equal to at least one-twelfth of the circumference of the balloon, but it need not exceed 8 feet.

(D) The width of the letters and figures of all marks shall be at least two-thirds of the height, and the width of the stroke shall be at least one-sixth of the height. The letters and figures shall be painted in plain black type on a white background or in any color on any background, but there must be a strong contrast between the two. The letters and numbers must be uniform in shape and size. A space equal to at least one-half of the width of a letter shall be left between each figure or letter.

Sec. 42. Other Symbols and Marks.

Except with the approval of the Secretary of Commerce, no design, mark, character, symbol, or description shall be placed upon aircraft if said design, etc., modifies, adds to, or subtracts from, or confuses the assigned mark or impairs or destroys its visibility.

Sec. 43. License and Identification Plates.

The license number or identification mark, with the name and residence of the owner, will be inscribed upon a metal plate furnished by the Secretary of Commerce. It must be affixed to the fuselage in a prominent place, but this section shall not apply to public aircraft of the United States used exclusively in the governmental service.

The plate will distinguish on its face between licensed and unlicensed aircraft.

CHAPTER 5

LICENSING OF PILOTS

Sec. 44. Pilots, Law of.

"The Secretary of Commerce shall by regulation * * * provide for the periodic examination and rating of airmen serving in connection with aircraft of the United States as to their qualifications for such service." (Sec. 3 (c).)

"The term 'airman' means any individual (including the person in command and any pilot, mechanic, or member of the crew) who engages in the navigation of aircraft while under way, and any individual who is in charge of the inspection, overhauling, or repairing of aircraft." (Sec. 9 (k).)

"It shall be unlawful * * * to serve as an airman in connection with any aircraft registered as an aircraft of the United States * * * without an airman certificate or in violation of the terms of any such certificate." (Sec. 11 (a) (4).)

"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of \$500." (Sec. 11 (b).)

Sec. 45. Application of the Law.

For the purpose of this chapter, persons in command of or piloting licensed aircraft in flight will be classed as pilots.

Sec. 46. Classification of Pilots.

Licensed pilots are classified as commercial or private pilots. Commercial pilots are licensed as transport, limited commercial, or industrial pilots. Private pilots are designated as private pilots (without other qualifications) or as student pilots. A person may hold a plurality of licenses, such as a pilot's and mechanic's license. A transport pilot will not be issued other classes of pilot's licenses.

Sec. 47. Privileges and Restriction of Licensed Pilots.

Except as otherwise provided in these regulations, the privileges conferred and restrictions imposed upon licensed pilots are as follows:

(A) Transport pilots may pilot any type of licensed aircraft but not unlicensed aircraft carrying persons or property for hire. Transport pilots shall have all of the privileges of navigating aircraft conferred

upon other classes of pilots, which shall include the right to instruct students in the operation of aircraft in flight.

(B) Limited commercial pilots shall have all of the privileges conferred and be subject to all of the restrictions imposed upon transport pilots, except they shall not pilot aircraft carrying persons for hire outside of the areas mentioned in their licenses, nor shall they, for hire, instruct students in the operation of aircraft in flight.

(C) Industrial pilots may pilot any type of licensed aircraft not carrying persons for hire but shall not pilot unlicensed aircraft carrying either persons or property for hire and shall not, for hire, instruct students in the operation of aircraft in flight.

(D) Private pilots, not designated as students, may pilot licensed aircraft but shall not carry persons or property for hire in licensed or unlicensed aircraft. Private pilots designated as students are licensed only for the purpose of piloting licensed aircraft when receiving flying instructions and such student pilots shall not pilot licensed aircraft carrying persons or property for hire or for any other purpose than receiving flying instructions nor within any other area than that specified in their licenses. Private pilots shall not, for hire, instruct students in the operation of aircraft in flight.

Sec. 48. Applications for Pilots' Licenses.

An application for a pilot's license must be filed, under oath, with the Secretary of Commerce upon blanks furnished for that purpose. An applicant for a pilot's license, including a student's pilot license, must appear for a physical examination before a physician designated by the Secretary of Commerce and pass such examination, unless he is exempt under these regulations.

Sec. 49. Character, Age, and Citizenship Qualifications.

An applicant for a pilot's license must be of good moral character. The minimum age requirements are 16 years for private pilots and 18 years for industrial, limited commercial, and transport pilots. A private pilot may be a citizen of any country. An industrial, limited commercial, or transport pilot must be (1) a citizen of the United States, or (2) a citizen of a foreign country which grants reciprocal commercial-pilot privileges to citizens of the United States on equal terms and conditions with citizens of such foreign country, or (3) an alien who has filed his declaration of intention to become a citizen of the United States

and advises the Secretary of Commerce of the serial number of such declaration, the date thereof, and the court in which filed. He must diligently and successfully prosecute the naturalization proceedings under penalty of the revocation of his pilot's license and from time to time must keep the Secretary of Commerce advised of the status of such proceedings.

Sec. 50. Flying Experience Requirements.

An applicant must have at least the following flying experience:

(A) **TRANSPORT PILOTS.**—Two hundred hours of solo flying, of which at least five hours must have been within the last preceding 60 days prior to the filing of the application.

(B) **LIMITED COMMERCIAL PILOTS.**—The same solo flying required of industrial pilots.

(C) **INDUSTRIAL PILOTS.**—Fifty hours of solo flying, of which at least 5 hours must have been within the last preceding 60 days prior to the filing of the application.

(D) **PRIVATE PILOTS.**—Private pilots not designated as students, 10 hours solo flying, of which at least 2 hours must have been within the last preceding 60 days prior to the filing of the application.

Sec. 51. Pilot's Physical Qualification.

The physical examinations provided for herein must be accomplished before the practical and theoretical tests will be given. The qualifications are as follows:

(A) **PRIVATE PILOTS.**—Absence of organic disease or defect which would interfere with safe handling of an airplane under the conditions of private flying; visual acuity of at least 20/40 in each eye; less than 20/40 may be accepted if the pilot wears a correction in his goggles bringing his vision approximately to normal and has normal judgment of distance without correction (however, in the case of student pilots this will not apply, but if a student has 20/50 in one eye and 20/40 or better in the other, with normal judgment of distance, without correction, he may be accepted if his physical condition is satisfactory, and if his vision can be corrected approximately to normal by goggles); good judgment of distance; no diplopia in any position; normal visual fields and color vision; no organic disease of eye or internal ear.

(B) **INDUSTRIAL PILOTS.**—Absence of any organic disease or defect which would interfere with the safe handling of an airplane; visual

acuity of not less than 20/30 in each eye, although in certain instances less than 20/30 may be accepted if the applicant wears a correction to 20/20 in his goggles and has good judgment of distance without correction; good judgment of distance; no diplopia in any field; normal visual fields and color vision; absence of organic disease of the eye, ear, nose, or throat.

(C) LIMITED COMMERCIAL PILOTS.—The same physical qualifications prescribed for transport pilots.

(D) TRANSPORT PILOTS.—Good past history; sound pulmonary, cardiovascular gastrointestinal, central nervous, and genito-urinary systems; freedom from material structural defects or limitations; freedom from disease of the ductless glands; normal central, peripheral, and color vision; normal judgment of distance; only slight defects of ocular muscle balance; freedom from ocular disease; absence of obstructive or diseased conditions of the ear, nose, and throat; no abnormalities of equilibrium that would interfere with flying.

(E) WAIVERS.—In the case of trained, experienced flyers the Secretary of Commerce may grant waivers for physical defects designated as disqualifying by these regulations when in his opinion the experience of the pilot will compensate for the defect. A waiver once granted will hold indefinitely so long as the defect for which it was granted has not increased or unless canceled by the Secretary of Commerce.

Sec. 52. Exemption from Prescribed Physical Examination.

An applicant for a pilot's license (or its renewal) will be exempt from the physical examination prescribed in these regulations upon filing with the Secretary of Commerce a certified copy of the examination for flying in the United States Army, Navy, or Marine Corps made within six months of the date of filing his application for his pilot's license or its renewal, provided his physical qualifications as shown by such copy of the examination are not less than those required by these regulations for the class of license for which he applies.

Sec. 53. Pilots' Examinations and Tests.

Unless exempt under these regulations, candidates must pass the following examinations and tests:

(A) TRANSPORT PILOTS.—(1) Examination on the air traffic rules and those portions of the Air Commerce Regulations pertaining to

pilots' privileges and limitations and to the inspection and operation of aircraft.

(2) Practical and theoretical examination in elementary engine and plane mechanics and rigging and a theoretical examination in the fundamentals of meteorology and air navigation.

(3) Practical flight test, as follows:

(a) In addition to normal take-offs and landings, the following maneuvers will be required: From 1,500 feet, with engine throttled, make a 360° turn and land in normal landing attitude, by wheels touching ground in front of and within 200 feet of a line designated by examiner for the Department of Commerce.

(b) From 1,000 feet, with engine throttled, make a 180° turn and land in normal landing attitude, by wheels touching ground in front of and within 200 feet of a line designated by examiner for the Department of Commerce.

(c) A series of five gentle and three steep figure-8 turns from 800 to 1,000 feet, respectively. Spiral in one direction from 2,000 feet, with engine throttled, and land in normal-landing attitude by wheels touching ground in front of and within 200 feet of a line designated by examiner for the Department of Commerce.

(d) Fly in emergency maneuvers, doing spirals, side slips, climbing turns, and recovering from stalls.

(e) Fly over a triangular or rectangular course at least 100 miles, landing at place of take-off within at least five hours. This flight shall also include two obligatory landings, not at point of departure, when craft must come to rest. The course will be designated and the candidate will be furnished with route information by the examiner for the Department of Commerce at time of departure, and the examiner for the Department of Commerce will determine whether the course was correctly followed and whether obligatory landings were satisfactory. Upon the presentation of satisfactory proof that the candidate has engaged in solo cross-country flights a distance of at least 100 miles within one year preceding the date of his application, the flight specified in this subsection will be omitted.

(f) Cross-wind landings and take-offs.

(B) LIMITED COMMERCIAL PILOTS.—The same examinations and tests as are prescribed for transport pilots, except the cross-country flight and the examination on elementary meteorology and navigation.

(C) **INDUSTRIAL PILOTS.**—(1) Examination on the air traffic rules and practical and theoretical examination in elementary engine and plane mechanics and rigging and those portions of the Air Commerce Regulations pertaining to pilots' privileges and limitations and to the inspection and operation of aircraft.

(2) The practical flight tests prescribed for transport pilots, except the distance for the cross-country flight which shall be 60 miles.

(D) **PRIVATE PILOTS.**—(1) Examination on the air traffic rules and those portions of the Air Commerce Regulations pertaining to pilots' privileges and limitations and to the inspection and operation of aircraft.

(2) The practical flight test specified in subparagraph 3 (c) of section 53 (A) and three satisfactory landings to a full stop. A private pilot, classed as a student, will be licensed without being required to pass the examination and tests prescribed in this subparagraph.

(E) **REEXAMINATION.**—Applicants for pilots' licenses who have failed to successfully accomplish the prescribed theoretical or practical tests may apply for reexamination at any time after the expiration of 90 days from the date of such failure.

If the physical examination has expired for the class of license for which application has been made, a new physical examination must be submitted.

The minimum passing grade for any subject in the foregoing theoretical examinations shall be 70 per cent.

Practical tests must be accomplished to the satisfaction of the examiner for the Department of Commerce.

Sec. 54. Place, Etc., of Examinations.

Examinations for pilots' licenses will be held at such times and places as the Secretary of Commerce shall designate. Such examinations and tests will be conducted by an examining officer designated by the Secretary of Commerce. Candidates for pilots' licenses must furnish the airplanes in which the flight tests are to be made, unless the Secretary of Commerce makes other provisions therefor.

Sec. 55. Duration and Renewal of Pilots' Licenses.

(A) Unless sooner revoked, transport and limited commercial pilots' licenses shall remain in force for six months and industrial and private pilots' licenses one year from date of issuance. Before any

license is renewed, the Secretary of Commerce may, in his discretion, require the holder of such license to undergo any of the theoretical or practical tests prescribed as requisites for the original license.

(B) Licenses will be renewed for like periods where the prescribed physical condition of the holder is shown by the same method as when the original license was issued, except that a transport or limited commercial pilot must prove that he has had at least 10 hours of solo flying within the last 60 days, industrial pilots at least 25 hours within the last year, and private pilots at least 10 hours within the last year.

(C) If an applicant for renewal has not had the required solo flying and applies for a renewal within six months after the expiration of his last license, a new license will be issued to him upon proof of his physical qualifications and the passing of the flight tests required for the class of license he last held.

(D) Upon application to and permission of the Secretary of Commerce the area for permissible flying of aircraft carrying passengers, for hire, designated in the license of limited commercial pilots, will be changed to other areas.

(E) Upon application and for good cause shown the licenses specified in this chapter may be extended for 60 days.

Sec. 56. Personal Possession of Pilots' Licenses.

The pilot's license shall be kept in his personal possession when he is piloting aircraft and must be presented for inspection upon the demand of any passenger or any authorized official or employee of the Department of Commerce or State or municipal officials charged with enforcing local regulations or laws involving Federal compliance.

Sec. 57. Pilots' Flight Records.

A licensed pilot must keep an accurate record of his flying time in a log book. It is the pilot's responsibility to obtain and maintain this log book.

Sec. 58. Carrying Passengers in Various Classes of Airplanes.

A licensed pilot, authorized to transport passengers, for hire, shall not do so in a type of aircraft which he has not previously operated within the last preceding 90 days for at least two hours, including 10 landings, 3 of which must have been to a full stop.

Sec. 59. Seaplane Piloting.

A licensed pilot shall not carry passengers, for hire, in a seaplane unless he has piloted a seaplane for at least two hours within the last preceding 90 days, except where he makes practice flights in the seaplane for at least one-half hour and takes it off and lands it at least ten times. At least three of the landings must be to a full stop.

Sec. 60. Pilots' Night-Flying Qualifications.

A transport or limited commercial pilot who has not had at least two hours of night solo flying within the last preceding 90 days shall not pilot aircraft carrying passengers, for hire, between one-half hour after sunset and one-half hour before sunrise, except where he takes off and lands between one-half hour after sunset and one-half hour before sunrise, at least ten times solo. At least three of such landings must be to a full stop.

Sec. 61. Meaning of Solo Flying.

As used in these regulations, a person is engaged in solo flying when he is the sole operator of the controls and is in command of aircraft, in flight.

Sec. 62. Suspension or Revocation of Licenses.

Pilots' licenses will be suspended or revoked for—

(A) Violating any provision of the air commerce act of 1926 or these regulations.

(B) Carelessness or inattention to duty.

(C) Unsound physical condition or any demonstration of incompetency in the operation or repair of aircraft.

(D) Being under the influence, or using, or having personal possession of intoxicating liquor, cocaine, or other habit-forming drugs while on duty.

(E) Refusal to exhibit license upon proper demand.

(F) Violating air traffic rules.

(G) Making any false statement in application for license or in any reports required to be submitted by these regulations.

(H) Carrying passengers who are obviously under the influence of intoxicating liquor, cocaine, or other habit-forming drugs.

(I) Piloting aircraft carrying passengers in excess of the original designed seating arrangements of the aircraft. Infants under 2 years of age are excepted, provided the maximum useful load is not exceeded.

(J) Doing any act in connection with aircraft which is contrary to the public safety or interest or detrimental to the morale of pilots or mechanics.

CHAPTER 6

LICENSING OF MECHANICS

Sec. 63. Mechanics, Law of.

"The Secretary of Commerce shall by regulation * * * provide for the periodic examination and rating of airmen serving in connection with aircraft of the United States as to their qualifications for such service." (Sec. 3 (c).)

"The term 'airman' means any individual (including the person in command and any pilot, mechanic, or member of the crew) who engages in the navigation of aircraft while under way, and any individual who is in charge of the inspection, overhauling, or repairing of aircraft." (Sec. 9 (k).)

"It shall be unlawful * * * to serve as an airman in connection with any aircraft registered as an aircraft of the United States * * * without an airman certificate or in violation of the terms of any such certificate." (Sec. 11 (a) (4).)

"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of \$500." (Sec. 11 (b).)

Sec. 64. Application of the Law.

For the purpose of this chapter, persons repairing or adjusting licensed aircraft in flight and persons in charge of the ground inspection, overhauling, or repairing of licensed aircraft will be classed as mechanics. A workman or mechanic may engage in the repair or overhaul of licensed aircraft without being licensed if such repair or overhaul is in charge of a licensed mechanic. An application for a mechanic's license must be filed, under oath, with the Secretary of Commerce upon blanks furnished for that purpose. An applicant for a mechanic's license is not required to take a physical examination.

Sec. 65. Classification of Mechanics.

Mechanics are licensed as engine or airplane mechanics. A person may hold a plurality of licenses, such as both classes of mechanic's licenses or a pilot's and mechanic's license.

Sec. 66. Mechanics' Qualifications and Examinations.

(A) An applicant for an engine mechanic's license must have had at least two years' experience on internal-combustion engines, one year of which must have been on aircraft engines. Such applicant will be licensed upon passing an examination on Air Commerce Regulations pertaining to the operation and inspection of aircraft and showing that he has sufficient knowledge of such engines and their accessories, including ignition systems, to properly inspect, maintain, repair, and overhaul the same.

(B) An applicant for an airplane mechanic's license must have had at least one year's actual experience in servicing aircraft. Such an applicant will be licensed upon passing an examination on Air Commerce Regulations pertaining to the operation and inspection of aircraft, showing he is sufficiently qualified in plane structure and rigging, including control systems, to properly inspect, maintain, repair, and overhaul the same.

(C) The examinations for both classes of license will be both theoretical and practical. The minimum passing grade in each subject covered shall be 70 per cent. A citizen of any country may be licensed if found qualified. Examinations for mechanics' licenses will be held at such times and places as the Secretary of Commerce shall designate. Such examinations and tests will be conducted by an examining officer designated by the Secretary of Commerce.

(D) Applicants for mechanic's licenses who have failed to successfully accomplish the prescribed theoretical or practical tests may apply for reexamination at any time after the expiration of 90 days from the date of such failure.

Sec. 67. Duration and Renewal.

Mechanics' licenses, unless sooner suspended or revoked, will remain in force for two years after date of issue and will be renewed for additional two-year periods upon proof that during the term of the last license the holder has rendered services under his license during at least one-half of the term thereof. Upon application and good cause

shown the Secretary of Commerce may extend the license for a period of not more than 60 days. Before any license is renewed, the Secretary of Commerce may, in his discretion, require the holder of such license to undergo any of the theoretical or practical tests prescribed as requisites for the original license.

Sec. 68. Personal Possession of Mechanics' Licenses.

A mechanic's license shall be kept in his personal possession when he is serving in connection with licensed aircraft and must be presented for inspection upon the demand of any passenger in or owner of repaired licensed aircraft upon which such mechanic has worked, or any authorized official or employee of the Department of Commerce or State or municipal officials charged with enforcing local regulations or laws involving Federal compliance.

Sec. 69. Suspension or Revocation of Licenses.

Mechanics' licenses will be suspended or revoked for—

(A) Violating any provision of the air commerce act of 1926 or these regulations.

(B) Carelessness or inattention to duty.

(C) Any demonstration of incompetency in the repair or overhaul of aircraft.

(D) Being under the influence, or using, or having personal possession of intoxicating liquor, cocaine, or other habit-forming drugs while on duty.

(E) Refusal to exhibit license upon proper demand.

(F) Making any false statement in application for license or in any reports required to be submitted by these regulations.

(G) Doing any act in connection with aircraft which is contrary to the public safety or interest or detrimental to the morale of pilots or mechanics.

CHAPTER 7

AIR TRAFFIC RULES

Sec. 70. Law.

"The Secretary of Commerce shall by regulation establish air traffic rules for the navigation, protection, and identification of aircraft, including rules as to safe altitudes of flight and rules for the

prevention of collisions between vessels and aircraft." (Air commerce act of 1926, sec. 3 (e).)

Sec. 71. Unlawful Acts.

"It shall be unlawful * * * to navigate any aircraft otherwise than in conformity with the air traffic rules." (Sec. 11 (a) (5).)

Sec. 72. Penalty.

"Any person who violates any provision of subdivision (a) of this section * * * shall be subject to a civil penalty of \$500." (Sec. 11 (b).)

Sec. 73. Application of the Law.

"In order to protect and prevent undue burdens upon interstate and foreign air commerce the air traffic rules are to apply whether the aircraft is engaged in commerce or noncommercial, or in foreign, interstate, or intrastate navigation in the United States, and whether or not the aircraft is registered or is navigating in a civil airway." (Statement of managers accompanying conference report, Air Commerce Act of 1926.)

Sec. 74. Flying Rules.

(A) **RIGHT-SIDE TRAFFIC.**—Aircraft flying in established civil airways, when it is safe and practicable, shall keep to the right side of such airways.

(B) **GIVING-WAY ORDER.**—Craft shall give way to each other in the following order:

- (1) Airplanes.
- (2) Airships.
- (3) Balloons, fixed or free.

An airship not under control is classed as a free balloon. Aircraft required to give way shall keep a safe distance, having regard to the circumstances of the case. Three hundred feet will be considered a minimum safe distance.

(C) **GIVING-WAY DUTIES.**—If the circumstances permit, the craft which is required to give way shall avoid crossing ahead of the other. The other craft may maintain its course and speed, but no engine-driven craft may pursue its course if it would come within 300 feet of another craft, 300 feet being the minimum distance within which aircraft, other than military aircraft of the United States engaged in

military maneuvers and commercial aircraft engaged in local industrial operations, may come within proximity of each other in flight.

(D) CROSSING.—When two engine-driven aircraft are on crossing courses the aircraft which has the other on its right side shall keep out of the way.

(E) APPROACHING.—When two engine-driven aircraft are approaching head-on, or approximately so, and there is risk of collision, each shall alter its course to the right, so that each may pass on the left side of the other. This rule does not apply to cases where aircraft will, if each keeps on its respective course, pass more than 300 feet from each other.

(F) OVERTAKING.—(1) *Definition*.—An overtaking aircraft is one approaching another directly from behind or within 70° of that position, and no subsequent alteration of the bearing between the two shall make the overtaking aircraft a crossing aircraft within the meaning of these rules or relieve it of the duty of keeping clear of the overtaken craft until it is finally past and clear.

(2) *Presumption*.—In case of doubt as to whether it is forward or abaft such position it should assume that it is an overtaking aircraft and keep out of the way.

(3) *Altering Course*.—The overtaking aircraft shall keep out of the way of the overtaken aircraft by altering its own course to the right, and not in the vertical plane.

(G) HEIGHT OVER CONGESTED AND OTHER AREAS.—Exclusive of taking off from or landing on an established landing field, airport, or on property designated for that purpose by the owner, and except as otherwise permitted by section 79, aircraft shall not be flown—

(1) Over the congested parts of cities, towns, or settlements, except at a height sufficient to permit of a reasonably safe emergency landing, which in no case shall be less than 1,000 feet.

(2) Elsewhere at height less than 500 feet, except where indispensable to an industrial flying operation.

(H) HEIGHT OVER ASSEMBLY OF PERSONS.—No flight under 1,000 feet in height shall be made over any open-air assembly of persons except with the consent of the Secretary of Commerce. Such consent will be granted only for limited operations.

(I) ACROBATIC FLYING.—(1) Acrobatic flying means intentional maneuvers not necessary to air navigation.

(2) No person shall acrobatically fly an aircraft—

(a) Over a congested area of any city, town, or settlement.

(b) Over any open-air assembly of persons or below 2,000 feet in height over any established civil airway, or at any height over any established airport or landing field, or within 1,000 feet horizontally thereof.

(c) Any acrobatic maneuvers performed over any other place shall be concluded at a height greater than 1,500 feet.

(d) No person shall acrobatically fly any airplane carrying passengers for hire.

(e) *Dropping Objects or Things.*—When an aircraft is in flight the pilot shall not drop or release, or permit any person to drop or release, any object or thing which may endanger life or injure property, except when necessary to the personal safety of the pilot, passengers, or crew.

(J) SEAPLANES ON WATER.—Seaplanes on the water shall maneuver according to the laws and regulations of the United States governing the navigation of water craft, except as otherwise provided herein.

(K) TRANSPORTING EXPLOSIVES.—The transporting of any explosives other than that necessary for signaling or fuel for such aircraft while in flight or materials for industrial and agricultural spraying (dusting) is prohibited, except upon special authority obtained from the Secretary of Commerce.

Sec. 75. Take-off and Landing Rules.

(A) METHOD.—Take-offs and landings shall be made upwind when practicable. The take-off shall not be commenced until there is no risk of collision with landing aircraft and until preceding aircraft are clear of the field. Aircraft when taking off or landing shall observe the traffic lanes indicated by the field rules or signals. No take-off or landing shall be made from or on a public street or highway without the consent of the local governing authority and the approval of the Secretary of Commerce.

(B) COURSE.—If practicable, when within 1,000 feet horizontally of the leeward side of the landing field the airplane shall maintain a direct course toward the landing zone.

(C) RIGHT OVER GROUND PLANES.—A landing plane has the right of way over planes moving on the ground or taking off.

(D) **GIVING WAY.**—When landing and maneuvering in preparation to land, the airplane at the greater height shall be responsible for avoiding the airplane at the lower height and shall, as regards landing, observe the rules governing overtaking aircraft.

(E) **DISTRESS LANDINGS.**—An aircraft in distress shall be given free way in attempting to land.

Sec. 76. Lights.

(A) **ANGULAR LIMITS.**—The angular limits laid down in these rules will be determined as when the aircraft is in normal flying position.

(B) **AIRPLANE LIGHTS.**—Between one-half hour after sunset and one-half hour before sunrise airplanes in flight must show the following lights:

(1) On the right side a green light and on the left side a red light, each showing unbroken light between two vertical planes whose dihedral angle is 110° when measured to the left and right, respectively, from dead ahead. These lights shall be visible at least 2 miles.

(2) At the rear and as far aft as possible a white light shining rearward, visible in a dihedral angle of 140° bisected by a vertical plane through the line of flight and visible at least 3 miles.

(C) **AIRSHIP LIGHTS.**—Between one-half hour after sunset and one-half hour before sunrise airships shall carry and display the same lights that are prescribed for airplanes, excepting the side lights shall be doubled horizontally in a fore-and-aft position, and the rear light shall be doubled vertically. Lights in a pair shall be at least 7 feet apart.

(D) **BALLOON LIGHTS.**—A free balloon, between one-half hour after sunset and one-half hour before sunrise, shall display one white light not less than 20 feet below the car, visible for at least 2 miles. A fixed balloon, or airship, shall carry three lights—red, white, and red—in a vertical line, one over the other, visible at least 2 miles. The top red light shall be not less than 20 feet below the car, and the lights shall be not less than 7 nor more than 10 feet apart.

(E) **LIGHTS WHEN STATIONARY.**—(1) Between one-half hour after sunset and one-half hour before sunrise all aircraft which are on the surface of water and not under control, or which are moored or anchored in navigation lanes, shall show a white light visible for at least 2 miles in all directions.

(2) Balloon and airship mooring cables between one-half hour after sunset and one-half hour before sunrise shall show groups of 3 red lights at intervals of at least every 100 feet, measured from the basket, the first light in the first group to be approximately 20 feet from the lower red balloon light. The object to which the balloon is moored on the ground shall have a similar group of lights to mark its position.

Sec. 77. Day Marks of Masts, Etc.

By day, balloon and airship mooring cables shall be marked with tubular streamers not less than 8 inches in diameter and 7 feet long and marked with alternate bands of white and red, 20 inches in width. The object to which the balloon or airship is moored on the ground shall have the same kind of streamers, which must be in the same position as the lights specified herein.

Sec. 78. Signals.

(A) DISTRESS.—The following signals, separately or together, shall, where practicable, be used in case of distress:

- (1) The international signal, S O S, by radio.
- (2) The international-code flag signal of distress, NC.
- (3) A square flag having either above or below it a ball, or anything resembling a ball.

(B) SIGNAL WHEN COMPELLED TO LAND.—When an aircraft is forced to land at night at a lighted airport it shall signal its forced landing by making a series of short flashes with its navigation lights if practicable to do so.

(C) FOG SIGNALS.—In fog, mist, or heavy weather an aircraft on the water in navigation lanes, when its engines are not running, shall signal its presence by a sound device emitting a signal for about five seconds in two-minute intervals.

Sec. 79. Deviation from Air Traffic Rules.

The air traffic rules may be deviated from when special circumstances render a departure necessary to avoid immediate danger or when such departure is required because of stress of weather conditions or other unavoidable cause.

CHAPTER 8

MISCELLANEOUS

Sec. 80. Civil Penalties.

"Any person who (1) violates any provision of subdivision (a) of this section or any entry or clearance regulation made under section 7, or (2) any customs or public health regulation made under such section, or (3) any immigration regulation made under such section, shall be subject to a civil penalty of \$500, which may be remitted or mitigated by the Secretary of Commerce, the Secretary of the Treasury, or the Secretary of Labor, respectively, in accordance with such proceedings as the Secretary shall by regulation prescribe * * *." (Air commerce act of 1926, sec. 11 (b).)

Sec. 81. Penalty proceedings.

The Secretary of Commerce, or his duly authorized representative, will notify all persons of the incursion of penalties subject to mitigation or remission by the Secretary, and any person charged with a civil penalty may transmit to the Secretary of Commerce, within the time prescribed in the notification of such penalty, an affidavit stating the facts upon which the request for mitigation or remission is based. The Secretary of Commerce will then determine whether or not the penalty will be mitigated or remitted, and the person making the request will be notified accordingly.

Sec. 82. Waiver of Regulations.

The Secretary of Commerce may waive any of the requirements of these regulations when, in his discretion, the particular facts justify such waiver.

Sec. 83. Savings Clause.

An aircraft required to be licensed under the air commerce act of 1926 may operate under a letter of authority from the Secretary of Commerce or his duly authorized representative pending the official inspection of such aircraft, provided an application for aircraft license is on file with the Secretary of Commerce and all the provisions of these regulations have been complied with.

In so far as these regulations amend the existing regulations they shall become effective on June 1, 1928, except as to sections 10 and 11, which shall become effective on August 1, 1928.

SECTION XV

NOMENCLATURE FOR AERONAUTICS

BY THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

Accelerometer—An instrument for indicating, measuring, or recording accelerations.

Aerodynamics—The branch of dynamics which treats of the motion of air and other gaseous fluids and of the forces acting on solids in motion relative to such fluids.

Aeronautics—The science and art pertaining to the flight of aircraft.

Aerostat—A generic term for aircraft whose support is chiefly due to buoyancy derived from aerostatic forces. The immersed body consists of one or more bags, cells, or other containers, filled with a gas which is lighter than air.

Syn.—*Lighter-than-air Craft*. Includes airship and balloon, *q. v.*

Aerostatics—The science that treats of the equilibrium of gaseous fluids and of solid bodies immersed in them.

As an aeronautic term, it relates to those properties of lighter-than-air craft which are due to the buoyancy of the air.

Aerostation—The art of operating aerostats.

Aileron—A hinged or pivoted movable auxiliary surface of an airplane, usually part of the trailing edge of a wing, the primary function of which is to impress a rolling moment on the airplane.

Aircraft—Any weight-carrying device or structure designed to be supported by the air, either by buoyancy or by dynamic action.

Air duct—A tube, usually of fabric, supplying air for filling or for maintaining pressure in air-filled parts of an aerostat.

a. The duct joining the vertical and lateral lobes of a kite balloon. Sometimes called “interconnecting sleeve” or “trousers” (British).

b. The duct leading from the air scoop or blower of a non-rigid or semirigid airship to the ballonnet or ballonets.

- Airfoil**—Any surface designed to be projected through the air in order to produce a useful dynamic reaction.
- Airfoil section (or profile)**—A cross-section of an airfoil made by a plane parallel to a specified reference plane. A line perpendicular to this plane is called the axis of the airfoil.
- Air log**—An instrument for measuring the linear travel of an aircraft relative to the air. One form consists of a windmill with a revolution counter.
- Airplane**—A mechanically driven aircraft, heavier than air, fitted with fixed wings, and supported by the dynamic action of the air.
- Airplane, pusher**—An airplane with the propeller or propellers in the rear of the main supporting surfaces.
- Airplane, tandem**—An airplane with two or more sets of wings of substantially the same area (not including the tail unit) placed one in front of the other and on about the same level.
- Airplane, tractor**—An airplane with the propeller or propellers forward of the main supporting surfaces.
- Airport**—A locality, either of water or land, which is adapted for the landing and taking off of aircraft and which provides facilities for shelter, supply, and repair of aircraft; or a place used regularly for receiving or discharging passengers or cargo by air.
- Air scoop**—A projecting scoop which uses the wind or slip stream to maintain air pressure in the interior of the ballonnet of an aerostat. A similar device is sometimes used on airplanes to produce ventilation.
- Airship**—An aerostat provided with a propelling system and with means of controlling the direction of motion. When its power plant is not operating, it acts like a free balloon.
- Non-rigid**—An airship whose form is maintained by the internal pressure in the gas bags and ballonets.
- Rigid**—An airship whose form is maintained by a rigid structure.
- Semirigid**—An airship whose form is maintained by means of a rigid or jointed keel in conjunction with internal pressure in the gas containers and ballonets.
- The term "airship" is sometimes incorrectly applied to heavier-than-air craft either in full or as "ship." This is a slang use of the word and should be avoided.

Air speed—The speed of an aircraft relative to the air. Its symbol is V .

Air speed meter:

Air-speed indicator—An instrument for indicating the speed of an aircraft relative to the air. It is actuated by the pressure developed in a suitable pressure nozzle or against a suitable obstruction and is graduated to give true air speed at a standard air density.

The speed indicated by the instrument is termed the "indicated air speed." (The indicated speed is a direct measure of the lift or drag exerted on the airplane at any altitude. Stalling at all altitudes occurs for the same value of the indicated speed.)

True air-speed meter—An instrument for measuring the true speed of an aircraft relative to the air. The Biram and Robinson anemometers are of this type.

Airway—An air route between air-traffic centers which is over terrain best suited for emergency landings, with landing fields at intervals equipped with aids to air navigation and a communication system for the transmission of information pertinent to the operation of aircraft.

The term "airway" may apply to an air route for either landplanes or seaplanes or both.

Alarm, gas-cell—A device, fitted adjacent to a gas cell, which indicates or warns when a predetermined limiting pressure has been reached in the gas cell. Also called "pressure alarm."

Altigraph—An altimeter equipped with a recording mechanism. Present instruments are of the aneroid type. The chart, driven by clockwork, is usually graduated in feet or meters, in accordance with some empirical or arbitrary pressure-temperature-altitude formula. In other words, it is a barograph whose scale is designed to read heights.

Altimeter—An instrument for measuring or indicating the elevation of an aircraft above a given datum plane.

Altimeter, aneroid—An altimeter, the indications of which depend on the deflection of a pressure-sensitive element. The graduations of the dial correspond to an empirical or arbitrary pressure-temperature-altitude formula.

Altimeter, electrical-capacity—An altimeter, the indications of which depend on the variation of an electrical capacity with distance from the earth's surface.

- Altimeter, engine**—An altimeter for indicating the altitude corresponding to the pressure produced in the intake manifold of a supercharged engine.
- Altimeter, optical**—An altimeter, the indications of which depend on the manipulation of a suitable optical system.
- Altimeter, sound-ranging**—An altimeter, the indications of which depend on the measurement of the time required for a sound wave to travel from the aircraft to the earth and back.
- Amphibian**—An airplane designed to rise from and alight on either land or water.
- Anchor, sea**—An open fabric bag carried on an aircraft and arranged to offer considerable resistance when towed mouth first through the water. Tripping or collapsing devices may be incorporated in it. Also called "drogue."
- Anchorage, snatch-block**—An anchorage set in the ground for a snatch block used with a yaw line from a mooring mast. The anchorages may be of concrete or timber and are usually arranged at equal intervals around the circumference of a circle whose center is the mast; may also be applied to any anchorage for a snatch block used in hauling down an airship or kite balloon.
- Anemometer**—An instrument for indicating or measuring the speed of an air stream.
- Angle, aileron**—The angular displacement of an aileron from its neutral position. It is positive when the trailing edge of the aileron is below the neutral position.
- Angle, critical**—An angle of attack at which the flow about an airfoil changes abruptly with corresponding abrupt changes in the lift and drag.
- Angle, downwash**—The angle through which an air stream is deflected by any lifting surface of an airplane. It is measured in a plane parallel to the plane of symmetry and is denoted by the symbol ϵ .
- Angle, drift**—The horizontal angle between the longitudinal axis of an aircraft and its path relative to the ground.
- Angle, effective helix**—The angle of the helix described by a particular point on a propeller blade as the airplane moves forward through air otherwise undisturbed. It is equal to the angle whose tangent is the ratio of the velocity of flight to the product of the four quanti-

ties: 2π , r (the distance from the axis to the point in question), and n (the number of revolutions per second), *i.e.*,

$$\Phi = \tan^{-1} \left(\frac{V}{2\pi rn} \right)$$

Angle, elevator—The angular displacement of the elevator from its neutral position. It is positive when the trailing edge of the elevator is below the neutral position.

Angle, landing—The acute angle between the line of thrust of an airplane and the horizontal when the airplane is resting on level ground in its natural position. Also called “ground angle.”

Angle, longitudinal dihedral—The difference in angle of wing setting and of stabilizer setting. (This angle is positive when the angle of stabilizer setting, referred to the thrust line, is less than the angle of wing setting.)

Angle, minimum gliding—The acute angle between the horizontal and the most nearly horizontal path along which an airplane can descend steadily in still air when the propeller is giving no thrust.

Angle of attack—The acute angle between the chord of an airfoil and its direction of motion relative to the air. (This definition may be extended to other bodies than airfoils.) Its symbol is α .

Angle of incidence of wing—See *Angle of wing setting*.

Angle of pitch—The acute angle between two planes defined as follows: One plane includes the lateral axis of the aircraft and the direction of the relative wind; the other plane includes the lateral axis and the longitudinal axis. (In normal flight the angle of pitch is, then, the angle between the longitudinal axis and the direction of the relative wind.) This angle is denoted by Θ and is positive when the nose of the aircraft has risen.

Angle of roll, or angle of bank—The acute angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into a horizontal plane. This angle is denoted by Φ and is positive when the left wing is higher than the right.

Angle of stabilizer setting—The acute angle between the line of thrust of an airplane and the chord of the stabilizer.

Angle of wing setting—The acute angle between the plane of wing chord and the line of thrust. It may differ for each wing.

- Angle of yaw**—The acute angle between the direction of the relative wind and the plane of symmetry of an aircraft. This angle is denoted by Ψ and is positive when the aircraft has turned to the right.
- Angle, propeller-blade**—The acute angle between the chord of a propeller section and a plane perpendicular to the axis of rotation of the propeller. Usually called "blade angle."
- Angle, rudder**—The acute angle between the rudder and the plane of symmetry of the aircraft. It is positive when the trailing edge has moved to the left with reference to the normal position of the pilot.
- Angle, wind-dihedral or dihedral**—The acute angle between the transverse reference line in the wing surface and the lateral axis of the airplane projected on a plane perpendicular to the longitudinal axis. The dihedral angle is positive when the upper obtuse angle for the two wings is less than 180 degrees.
- Angle, zero-lift**—The angle of attack of an airfoil when its lift is zero.
- Antiflutter wire**—See *Wire (airship)*, antiflutter.
- Apparatus, water-recovery**—Apparatus carried on an airship for condensing and recovering the water contained in the exhaust gases of internal combustion engines in order to avoid the necessity of valving gas as the fuel is consumed.
- Appendix**—The tube, usually located at the bottom of a balloon, primarily used for inflation and deflation. In the case of a free balloon, it may also serve as an automatic-discharge opening. Originally applied to free balloons only. Should be restricted to the various types of balloons and not applied to airships.
- Appendix manhole**—See *Manhole, appendix*.
- Apron**—A hard surface area of considerable extent immediately in front of the entrance of a hangar or aircraft shelter which is used for the handling of aircraft or for repair in clear weather.
- Aspect ratio**—The ratio of span to mean chord of an airfoil, *i.e.*, the ratio of the square of the maximum span to the total area of an airfoil.
- Aspect ratio of propeller blade**—Half the ratio of propeller diameter to maximum blade width.
- Attitude**—The position of an aircraft as determined by the inclination of its axes to some frame of reference. If not otherwise specified, this frame of reference is fixed to the earth.

Aviation—The art of operating heavier-than-air craft.

Axes of an aircraft—Three fixed lines of reference, usually centroidal and mutually perpendicular. The longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis perpendicular to the other two is called the lateral axis. In mathematical discussions, the first of these axes, drawn from front to rear, is called the *X* axis; the second, drawn upward, the *Z* axis; and the third, running from right to left, the *Y* axis.

Balanced surface—A control surface which extends on both sides of the axis of the hinge or pivot in such a manner as to reduce the moment of the air forces about the hinge.

Ballast—Any substance, usually sand or water, carried in a balloon or airship and intended to be thrown out, if necessary, for the purpose of reducing the load carried and thus altering the aerostatic relations.

Ballonet—A compartment of variable volume constructed of fabric, or partitioned off, within the interior of a balloon or airship. It is usually partially inflated with air, under the control of valves, from a blower or from an air scoop. By the blowing in or letting out of air, it serves to compensate for changes of volume in the gas contained in the envelope and to maintain the gas pressure, thus preventing deformation or structural failure. By means of two or more ballonets, often used in non-rigid airships, the trim can also be controlled. The ballonet should not be confused with gas cell.

Balloon—An aerostat without a propelling system.

Barrage—A small captive balloon, used to support wires or nets which are intended as a protection against attacks by aircraft.

Captive—A balloon restrained from free flight by means of a cable attaching it to the earth.

Constant pressure—A supply balloon arranged to maintain a constant pressure of gas in a moored or docked aerostat.

Free—A balloon, usually spherical, whose ascent and descent may be controlled by use of ballast or with a loss of the contained gas, and whose direction of flight is determined by the wind.

Kite—An elongated form of captive balloon, fitted with lobes to keep it headed into the wind and usually deriving increased lift due to its axis being inclined to the wind.

Nurse—Sometimes used to refer to a constant-pressure balloon.

Observation—A captive balloon used to provide an elevated observation post.

Pilot—A small balloon sent up to show the direction and speed of the wind.

Propaganda—A small free balloon sent up without passengers but with a device by which papers or documents may be dropped at intervals.

Sounding—A small balloon sent up without passengers but with recording meteorological instruments.

Supply—A container made of heavy fabric employed as a portable means of storing gas at low pressure. It is usually too heavy to rise, even if free.

Triangulation—A small captive balloon used as a mark on which to sight in a triangulation survey.

Balloon bed—A mooring place on the ground for a captive balloon.

Balloon fabric—See *Fabric, balloon*.

Band:

Drip—See *Flap, drip*.

Mooring—A band of tape or webbing, over the top of a kite balloon, to which the mooring ropes are attached. It forms part of a mooring harness.

Suspension—A horizontal fabric band, securely fastened to the envelope of a balloon or airship, and to which are attached the main suspensions of the basket or car, or the captive cable of a kite balloon.

Trajectory—A band of webbing carried in a special curve over the surface of the envelope of an airship to distribute the stresses due to the suspension of the car.

Bank—To incline an airplane laterally, *i.e.*, to rotate it about its longitudinal axis. Right-bank is to incline the airplane with the right wing down.

Also used as a noun to describe the position of an airplane when its lateral axis is inclined to the horizontal.

Bank, angle of—See *Angle of roll*.

Barograph—An instrument for recording the barometric or static pressure of the atmosphere.

Bar, suspension—A bar to which the supporting ropes of the basket of a balloon are secured. It is also fitted with ropes and toggles for

attaching to the basket suspensions from the balloon. Also called "trapeze bar."

Basket—The structure suspended beneath a balloon, for carrying passengers, ballast, etc.

It is usually used on a free or kite balloon.

Batonet—A special form of toggle, usually quite slender and truly cylindrical, except for the groove, and used to attach the rigging of a balloon or airship to a fabric loop or suspension band on the envelope.

Bay (body parts)—The portion of a face of a truss, or of a fuselage, between adjacent bulkheads or adjacent struts or frame positions.

Biplane—An airplane with two main supporting surfaces placed one above the other.

Blade back—The side of a propeller blade which corresponds to the upper surface of an airfoil.

Blade face—The surface of a propeller blade which corresponds to the lower surface of an airfoil. Sometimes called "thrust face," or "driving face."

Blade-width ratio—The ratio of the developed width of a propeller blade at any point to the circumference of a circle whose radius is the distance of that point from the propeller axis.

Blimp—A small, non-rigid airship. "Airship" is to be preferred.

Body—The fuselage or hull, or nacelle (including cowling and covering) and nacelle mounting.

Bonnet—See *Hood, valve*.

Bow-heavy—The condition of an airship which, when at rest in still air, trims with its axis inclined down by the bow. The term "bow-heavy" is preferred to "nose-heavy" in describing airships.

Bow-steadying line—See *Line, yaw*.

Brake mean effective pressure—The net unit pressure which, if applied during the power strokes to the pistons of an engine having no mechanical losses, would produce the given brake horsepower at the stated speed.

Breathing—The passage of air into or out of an aerostat, due to the changing of its volume.

Bridle—A sling of cordage or wire which has its ends fixed at two different points, to the bight of which a single line may be attached, either movable or fixed, thus distributing the pull of the single line to two

points or more in the case of a multiple bridle. This term is also used to refer to a towing or mooring line having two legs and intended to reduce yawing when towing or mooring.

Bull's-eye—A circular thimble.

Buoyancy—The upward air force on an aerostat which is derived from aerostatic conditions. It is equal to the weight of the air displaced.

Buoyancy, center of (aerostat)—The center of gravity of the volume of the contained gas.

Burbling—The interruption of airflow over upper surface of wings interfering with pilot's control of plane at stalling speed.

Cabane—A framework for supporting the wings at the fuselage; also applied to the system of trussing used to support overhang in a wing.

Cable, axial—The axial member (usually steel-wire cable) sometimes fitted in a rigid airship. It is attached to the central fitting of the radial or diametral wires of each main transverse and to the hull structure at bow and stern. Its purpose is to provide support for the radial or diametral wires in an axial direction and thus assist them to sustain the load which might be caused by unequal pressure in adjacent cells or by the airship's being pitched to a large angle.

Camber—The rise in the curve of an airfoil section from its chord, usually expressed as the ratio of the departure of the curve from the chord to the length of the chord. "Upper camber" refers to the upper surface of an airfoil and "lower camber" to the lower surface; "mean camber" is the mean of these two.

Capacity—The volume of the gas-containing portion of an aerostat.

Capacity, nominal gas—The volume of the envelope of gas cells of an aerostat under certain conditions of pressure and inflation which have been defined. It is rarely the same as the true full volume. This is usually very difficult to determine accurately, especially in the case of rigid airships. Sometimes called "volume."

Cap, bow—(1) A cap of metal or fabric used to reinforce the extreme forward ends of the bow stiffeners of a non-rigid or semirigid airship.

(2) The conical or cap-shaped structure at the extreme bow of a rigid airship to which the longitudinal girders are attached and which supports the bow mooring spindle.

Cap, nose—See *Cap, bow*, which is to be preferred.

Captive balloon—See *Balloon, captive*.

- Car**—That portion of an airship which is intended to carry power unit or units, personnel, cargo, or equipment. It may be suspended from the buoyant portion, or it may be built close up against it. It is not to be applied to parts of the keel of a rigid or semirigid airship which have been fitted for the purposes mentioned.
- Car, control**—The car of an airship in which controls are centralized and from which it is operated.
- Carrier, fin**—A frame to which the inboard edge of the fin of a non-rigid or semirigid airship is attached, so as to prevent the edge of the fin from sinking into the envelope.
- Car, side**—See *Car, wing*.
- Car, wing**—A car suspended off the center line of an airship. It is also called "side car."
- Catenary**—A line or length of cordage which is secured to or in a piece of fabric in the form of a catenary curve or a series of such curves.
- Ceiling:**
- Absolute**—The maximum height above sea level at which a given airplane would be able to maintain horizontal flight, assuming standard air conditions.
- Service**—The height above sea level, assuming standard air conditions, at which a given airplane ceases to be able to rise at a rate higher than a small specified one (100 feet per minute in the United States and England). This specified rate may be different in different countries.
- Ceiling, static**—The altitude in standard atmosphere, at which an aerostat is in static equilibrium after removal of all dischargeable weights.
- Cell, gas**—One of the gas-containing units fitted in a rigid airship. Sometimes called "gas bag."
- Center of pressure coefficient**—The ratio of the distance of the center of pressure from the leading edge to the chord length.
- Center of pressure of an airfoil section**—The point in the chord of an airfoil section, prolonged if necessary, which is at the intersection of the chord and the line of action of the resultant air force. Its abbreviation is C. P.
- Chord (of an airfoil section)**—The line of a straight-edge brought into contact with the lower surface of the section at two points; in the case of an airfoil having double-convex camber, the straight line

joining the leading and trailing edges. (These edges may be defined, for this purpose, as the two points in the section which are farthest apart.)

The line adjoining the leading and trailing edges should be used also in those cases in which the lower surface is convex except for a short, flat portion.

The method used for determining the chord should always be explicitly stated for those sections with regard to which ambiguity seems likely to arise.

Chord length—The length of the projection of the airfoil section on its chord. Its symbol is c .

Chord, mean, of a combination of wings—The ratio

$$\frac{c_1 S_1 + c_2 S_2 + c_3 S_3 + \dots}{S_1 + S_2 + S_3 + \dots}$$

where c_1, c_2, c_3 , etc., are the mean chords of various wings, and S_1, S_2, S_3 , etc., are their areas.

Chord, mean of a wing—The quotient obtained by dividing the wing area by the extreme dimension of the wing projection at right angles to the chord.

Chord wire—See *Wire (airship)*, *chord*.

Cloth—Fabric delivered by the bleachery or finisher before it has been proofed, doped, or specially treated for aeronautic use.

Cloth, ground—Canvas placed beneath an aerostat for its protection during inflation and deflation.

Cockpit—The open spaces in which the pilot and passengers are accommodated. When the cockpit is completely housed in it is called a cabin.

Compartment, control—A compartment in the control car of an airship from which all controls are operated. It may be compared to the pilot house of a ship.

Compass, induction—A compass, the indications of which depend on the current generated in a coil revolving in the earth's magnetic field.

Condenser, water-recovery—That part of the water-recovery apparatus which is devoted to the condensing of water in the exhaust gases. It may consist of a number of metal tubes or of a fabric box with appropriate inlets, outlets, and baffles.

Cone, axial—The cone-shaped fabric, fitting in the end of a gas cell of a rigid airship, which provides a gas-tight connection of the cell to the

axial cable and yet permits the cell some degree of freedom in its movements. A special form of conical sleeve.

Cone, danger—A pennant on the wire cable of a captive balloon to warn aircraft of its presence. Usually a hollow cone of light cloth.

Cone, mooring—The grooved conical member at the extreme bow of an airship which engages with a hollow cone at the top of the mooring mast and provides the coupling between the airship and the mooring mast.

Container, gas—See *Cell, gas*, which is to be preferred.

Controllability—The quality in an airplane which makes it possible for the pilot to change its altitude easily and with the exertion of but little force.

Controls—A general term applied to the means provided to enable the pilot to control the speed, direction of flight, altitude, and power of an aircraft.

Air controls—The means employed to operate the control surfaces of the aircraft.

Engine controls—The means employed to control the power output of the engines. (Control of speed may be effected by the air controls or the engine controls independently, or by either in conjunction with the other.)

Control stick—The vertical lever by means of which the longitudinal and lateral controls of an airplane are operated. Pitching is controlled by a fore-and-aft movement of the stick, rolling by a side-to-side movement.

Cord, rip—The rope running from the rip panel to the car or basket, the pulling of which tears off or rips the rip panel and causes immediate deflation.

Cover, outer—The outside covering of the hull of a rigid airship, usually of some kind of fabric. Sometimes called the "envelope."

Cover, valve—See *Hood, valve*.

Cowling—A removable covering which extends over or around the engine, and sometimes over a portion of the fuselage or nacelle as well.

Cradle :

Building—A support provided for the frame of a rigid airship or the keel of a semirigid airship during construction.

Docking—A support for the car of an airship while it is being inflated in the shed. Mostly used with rigid airships.

Crew, ground—See *Crew, landing*.

Crew, landing—A detail of men necessary for the landing and handling of an airship on the ground. A "ground crew."

Crow's-foot—A system of diverging short ropes for distributing the pull of a single rope.

An arrangement in which the strands of a cord are opened out so that they can be effectively cemented to a fabric surface.

Damping factor—The factor $e^{-\lambda t}$ in the equation of damped harmonic motion.

$$s = Ae^{-\lambda t} \sin pt.$$

Dead load—See *Weight, empty*, which is to be preferred.

Decalage—The acute angle between the wing chords of a biplane or multiplane.

Deflation—The act of removing gas and air from an aerostat.

Diaphragm, ballonet—The fabric partition between the gas and air compartments of the envelope of a non-rigid or semirigid airship or kite balloon.

Dihedral angle—See *Angle, wing-dihedral*

Dirigible—That can be directed; steerable; as a dirigible balloon. Its use as a noun to indicate an airship is improper.

Displacement—The mass of air displaced by the gas used for inflation. It may be expressed as a weight or volume. In the latter case it is usually called "volume."

Displacement, aerodynamic volume or air volume—The weight of a mass of air equal to the aerodynamic volume of the airship in N. A. C. A. standard atmosphere at sea level.

Dive—A steep descent, with or without power, in which the air speed is greater than the maximum speed in horizontal flight.

Divergence—A motion in which, after a disturbance from equilibrium, the body departs continuously, without oscillations, from its original state of motion.

Dock—A term sometimes applied to an airship shed.

Dope (airplane)—The liquid material applied to the cloth surfaces of airplanes to increase strength, to produce tautness by shrinking, and to act as a filler for maintaining air tightness.

Dope (airship)—The liquid material applied to rubberized airship fabric to increase gas tightness. In contrast with airplane dope, it does not cause shrinking

Dope (pigmented)—An aircraft dope to which a pigment has been added to make an opaque finish, or to protect it from the effects of sunlight.

Drag—The component parallel to the relative wind of the total air force on an aircraft or airfoil. Its symbol is D .

The absolute drag coefficient is C_D , as defined by the equation $C_D = \frac{D}{qS}$, in which D is the drag, q is the impact pressure ($= \frac{1}{2}\rho V^2$), and S is the effective area of the surface upon which the air force acts.

In the case of an airplane, that part of the drag due to the wings is called "wing drag;" that due to the rest of the airplane is called "structural drag" or "parasite resistance."

Induced—That portion of the wing drag induced by, or resulting from, the generation of the lift.

Profile—That portion of the wing drag which is due to friction and turbulence in the fluid and which would be absent in a nonviscous fluid.

Drag, mooring—A movable and/or variable weight, suspended from the afterpart of an airship's structure while moored at a mast, to aid in restraining the vertical and lateral motions of the stern of the airship.

Drift—The lateral velocity of an aircraft due to air currents.

Drift bar—A part of a drift meter or other instrument for indicating the apparent direction of motion of the ground relative to the fore-and-aft axis of the aircraft. It usually consists of a wire or arm which can be set along this direction of motion. *Cf.* drift.

Drift meter—An instrument for measuring the angle between the fore-and-aft axis of an aircraft and its path over the ground. One form consists of a drift bar provided with a suitable angular scale. (*Cf.* drift.) The instrument is graduated to read correctly when it is level.

Drip band—See *Flap, drip*.

Drip strip—See *Flap, drip*.

D-ring—A ring having (as the name implies) the shape of a capital D, to which rope suspensions are attached.

Drogue—See *Anchor, sea*.

Duralumin—An alloy of aluminum which is much used in aeronautics, especially for the structure of airships and airplanes. Its chemical composition and physical properties are about as follows:

Copper, 3.5 to 4.5 per cent.

Manganese, 0.4 to 1 per cent.

Magnesium, 0.2 to 0.75 per cent.

Aluminum, 92 per cent, minimum.

Tensile strength, ultimate, 55,000 pounds per square inch.

Tensile strength at elastic limit, 30,000 pounds per square inch.

Elongation of 2 inches at ultimate strength (test specimen $\frac{1}{2}$ inch wide), 18 per cent.

Specific gravity not more than 2.85.

Dynamic factor—The ratio between the load carried by any part of an aircraft when accelerating and the corresponding basic load.

Dynamic (or impact) pressure—The product $\frac{1}{2}\rho V^2$, where ρ is the density of the air and V is the relative speed of the air. It is the quantity measured by most air-speed instruments. Its symbol is q .

Earth induction compass—See *Compass, induction*.

Elevator—A movable auxiliary airfoil, the function of which is to impress a pitching moment on the aircraft. The elevator is usually hinged to the stabilizer.

Endurance—The maximum length of time an aircraft can remain in the air at a given speed and altitude.

Engine, barrel-type—An engine having its cylinders arranged equidistant from and parallel to the main shaft.

Engine, dry weight of an—The weight of the engine, including carbureter and ignition systems complete, propeller-hub assembly, reduction gears, if any, but excluding exhaust manifolds, oil, and water. If the starter is built into the engine as an integral part of the structure, its weight shall be included.

Engine, inverted—An engine having its cylinders below the crankshaft.

Engine, left-hand—An engine whose propeller shaft, to an observer facing the propeller from the antipropeller end of the shaft, rotates in a counter-clockwise direction.

Engine, radial—An engine having stationary cylinders arranged radially around a common crankshaft.

Engine, right-hand—An engine whose propeller shaft, to an observer facing the propeller from the antipropeller end of the shaft, rotates in a clockwise direction.

Engine, rotary—An engine having revolving cylinders arranged radially around a common fixed crankshaft.

- Engine, supercharged**—An engine with mechanical means for increasing the cylinder charge beyond that normally taken in at the existing atmospheric pressure and temperature.
- Engine, vertical**—An engine having its cylinders arranged vertically above the crankshaft.
- Engine, V-type**—An engine having its cylinders arranged in two rows, forming, in the end view, the letter V.
- Engine, W-type**—An engine having its cylinders arranged in three rows, forming, in the end view, the letter W. Sometimes called the "broad-arrow type."
- Entering edge**—See *Leading edge*.
- Envelope**—The outer-covering of an aerostat, usually of fabric. It may or may not be also the gas container. It may be divided by diaphragms into separate gas compartments or cells, and it may also contain internal air cells or ballonets.
- Equipment, ground**—See *Gear, ground*.
- Fabric, balloon**—The finished material, usually rubberized, of which balloon or airship envelopes are made.
- Biased**—Plied fabric in which the threads of the plies are at an angle to each other.
- Parallel**—Plied fabric in which the threads of the plies are parallel to each other.
- Fabric, gas-cell**—The fabric used in gas cells of rigid airships, usually goldbeater's skin fabric, *q. v.*
- Fabric, goldbeater's skin**—A gas-containing fabric consisting of a layer of light, fine, strong cloth, usually cotton, to which one or more layers of goldbeater's skins have been cemented. The skins are on the inside and are usually further protected by a coat of fine varnish. Usually used in the gas cells of rigid airships.
- Factor of safety**—The ratio of the ultimate strength of a member to the maximum probable load in that member in actual use.
- Fairing**—An auxiliary member or structure whose primary function is to reduce head resistance or drag of the part to which it is fitted (without, in general, contributing strength).
- Fin**—A fixed surface, attached to a part of the aircraft, parallel to the longitudinal axis, in order to secure stability; for example, tail fin, skid fin, etc. Fins are sometimes adjustable.

Fire wall—A fire-resistance transverse bulkhead, so set as to isolate the engine compartment from the other parts of the structure and thus to reduce the risk from fire in the engine compartment.

Fitting—A generic term for any small part used in the structure of an airplane or airship. If without qualification, a metal part is usually understood. It may refer to other parts, such as fabric fittings.

Fixed Surface—See *Fin*.

Flap, drip—A strip of fabric attached by one edge to the envelope of an aerostat so that rain runs off its free edge instead of dripping into the basket or car. It also assists in keeping the suspension ropes dry and non-conducting. Also called "drip band" and "drip strip."

Flap, pressure—A flap valve fitted in the outer cover or envelope of a rigid airship and arranged to permit the rapid flow of air in and out—particularly inward. The purpose is to facilitate the rapid equalization of the pressure of the air within the envelope with that of the surrounding air.

Flight, cross-country—A flight which necessitates leaving the vicinity of a regular landing field.

Flight indicator—See *Indicator, flight*.

Flight path—The path of the center of gravity of an aircraft with reference to the earth.

Float—A completely inclosed water-tight structure attached to an aircraft in order to give it buoyancy and stability when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float. The term "pontoon" is now obsolete.

Flying boat—A form of seaplane supported, when resting on the surface of the water, by a hull or hulls providing floatation in addition to serving as fuselages. For the central hull type, lateral stability is usually provided by wing-tip floats. The term "boat seaplane" is now obsolete.

Force, cross-wind—The component, perpendicular to the lift and to the drag, of the total air force on the aircraft or any part thereof. Its symbol is C , and its absolute coefficient C_c is defined by

$$C_c = \frac{C}{qS}$$

where q is the impact pressure ($= \frac{1}{2}\rho V^2$) and S is the effective area of the surface upon which the air force acts.

- Frame, field-handling**—A portable frame which may be attached to an airship when it is on the ground and which is intended to afford a grasp to more men than could get on the handling rails of the cars. These frames are rarely carried when in flight.
- Framing, stern**—All framework, aft of the cruciform girder, necessary to complete the shape and contour of a rigid airship.
- Fuel (or oil) consumption, specific**—The weight of fuel (or oil) consumed per brake horsepower-hour.
- Fuselage**—The structure, of approximately streamline form, to which are attached the wings and tail unit of an airplane. In general, it contains the power plant, passengers, cargo, etc.
- Fuselage, monocoque**—A type of fuselage construction wherein the structure consists of a thin shell of wood, metal, or other material, supported by ribs, frames, belt frames, or bulkheads, but usually without longitudinal members other than the shell itself. The whole is so disposed as to carry the stresses to which the structure is subjected.
- Gap**—The distance between the planes of the chords of any two adjacent wings, measured along a line perpendicular to the chord of the upper wing at any designated point of its leading edge. Its symbol is *G*.
- Gas bag**—See *Hull (airship)* and *Cell, gas*.
- Gas container**—See *Cell, gas*.
- Gassing**—The operation of replenishing a balloon with fresh gas to increase the purity or to make up for loss of gas.
- Gassing factor**—The quantity of aerostatic gas required to maintain an aerostat for 1 year. It is ordinarily expressed as a percentage of the gas volume.
- Gear, flotation**—An emergency gear attached to a landplane to permit alighting on the water and to provide buoyancy when resting on the surface of the water.
- Gear, ground**—The gear, or equipment, necessary for the landing and handling of an airship on the ground.
- Girder, box**—Any girder of rectangular section. Frequently used to refer to the rectangular, longitudinal members in the keel of a rigid airship from which fuel tanks and gas bags are suspended.
- Girder, cruciform**—The structure, consisting of vertical and horizontal transverse girders, which is fitted at the stern of a rigid airship for the purpose of supporting the inboard ends of the stern posts of

the fins or the rudder posts. It may be integral with the stern posts which form the afterends of the fins.

Girder, fin—A girder of a rigid airship which goes to make up the fin.

Girder, propeller reinforcing—A light additional member fitted in the structure of a rigid airship to reinforce those areas of the outer cover which are affected by the propeller wash.

Girder, walkway—The girder forming the support of a walkway through the keel or in other localities in a rigid or semirigid airship.

Gland—A short tube fitted to an envelope or gas bag in such a manner that a rope or line may slide through without leakage of gas or air.

Gland, manometer-tube—A gland fitted to the envelope of an aerostat to form a gas-tight connection for the tube leading to the manometer in the car. Same as "pressure-tube gland."

Gland, pressure-tube—See *Gland, manometer-tube*.

Glide—A descent with reference to the air at a normal angle of attack and without engine power sufficient for level flight in still air, the propeller thrust being replaced by a component of gravity along the line of flight. Also used as a verb.

Glider—A form of aircraft similar to an airplane, but without a power plant.

Gondola—The car of an airship. This use of the word is borrowed from the Italian via the German. "Car" is to be preferred.

Gore—The portion of the envelope of a balloon or airship included between two adjacent meridian seams.

Grab line—See *Line, handling*.

Grommet—A small ring of cord.

Ground angle—See *Angle, landing*.

Ground crew—See *Crew, landing*.

Ground equipment—See *Gear, ground*.

Ground-speed meter—An instrument for measuring the speed of an aircraft relative to the ground. In present types of instruments some reference line in the instrument must first be set parallel to the apparent direction of motion of the aircraft with reference to the ground before the speed measurement is made. This is usually accomplished by the use of a drift meter, the adjustment of which automatically orients the ground-speed meter properly. Thus,

both the magnitude and direction of the motion of the aircraft with reference to the ground are obtained.

Guy, yaw—See *Line, yaw*.

Hangar—A shelter for housing aircraft. More properly applied to heavier-than-air craft.

Harness, mooring—A system of webbing bands, fitted over the top of the envelope of a balloon, to which are attached the mooring ropes. Usually found only in kite balloons or observation balloons.

Height, pressure—The altitude at which the gas cells of a rigid airship are full, or the gas bag of a non-rigid airship is completely full of gas.

Helicopter—A form of aircraft whose sole support in the air is derived directly from the vertical component of the thrust produced by rotating airfoils.

Hog—A distortion of an airship in which the longitudinal axis becomes convex upward so that both ends droop.

Hood, gas-shaft—A hood, or cowl, located on the outer cover of a rigid airship at the outer end of a gas shaft. It is usually made of light wood and fabric and is faced to facilitate the escape of gas. Sometimes called "exhaust-gas hood."

In view of the possibility of confusion with the parts of an engine exhaust system, it is believed that "gas-shaft hood" is to be preferred.

Hood, maneuvering-valve—A hood, or cowl, located on the outer cover of a rigid airship just over a maneuvering valve. It is usually made of light wood or fabric and is faced to facilitate the escape of gas.

Hood, valve—The appliance, having the form of a hood or parasol which protects the valve of an airship or balloon against rain. Also called "valve cover" or "bonnet."

Horn—A short lever attached to a control surface of an aircraft. For example, aileron horn, rudder horn, elevator horn.

Horsepower of an engine, maximum—The maximum horsepower which an engine can develop.

Horsepower of an engine, rated—The average horsepower developed by an engine of a given type in passing the standard 50-hour endurance test.

Hull (airship)—The main structure of a rigid airship, consisting of a covered, elongated framework which incloses the gas cells and supports the cars and equipment. May also be applied to the complete

buoyant unit of any aerostat. In this latter sense, sometimes called "gas bag."

Hull (seaplane)—The portion of a flying boat which furnishes buoyancy when in contact with the surface of the water. It contains accommodations for the crew and passengers, usually incorporating the functions of a float and fuselage in one unit.

Impact pressure—See *Dynamic (or Impact) pressure*.

Inclinometer—An instrument for indicating the attitude of an aircraft. Inclinometers are termed fore-and-aft, lateral, or universal, according as they indicate inclination on the vertical plane through the fore-and-aft axis, or in the vertical plane through the lateral axis, or in both planes, respectively.

Inclinometer, absolute—An instrument which indicates the attitude of an aircraft with reference to the vertical. The indications of instruments of this type usually depend on gyroscopic action.

Inclinometer, relative—An instrument which indicates the attitude of an aircraft with reference to apparent gravity, *i.e.*, to the resultant of the acceleration of the aircraft and that due to gravity.

Indicator, air-speed—See *Air-speed meter*.

Indicator, ballonet-fullness—An instrument for indicating the volume of air in a ballonet.

Indicator, flight—An instrument in which a lateral inclinometer, a fore-and-aft inclinometer, and a turn indicator are combined to form a compact unit.

Indicator, gyroscopic turn—A turn indicator dependent on gyroscopic action.

Indicator, pitch—An instrument for indicating the existence of a pitching velocity of an aircraft. *Cf.* turn indicator.

Indicator, static turn—A turn indicator actuated by the difference in pressure between static tubes mounted near the wing tips equidistant from the plane of symmetry and in a plane parallel to the lateral axis.

Indicator, turn—An instrument for indicating the existence of an angular velocity of turn of an aircraft about the normal axis. In horizontal flight it indicates the presence of a yawing velocity. "Turn meter" is the term applied to certain types.

Indraft (inflow)—The flow of air from in front of the propeller into the blades.

Induction compass—See *Compass, induction*.

Inflation—The act of filling a balloon or airship with gas.

Inflow—See *Indraft*.

Jackstay—A longitudinal rigging provided to maintain the correct distance between various parts on fittings on an aerostat.

Keel (airship)—The assembly of members at the bottom of the hull of a semirigid or rigid airship which provides special strength to resist hogging and sagging and also serves to distribute the effect of concentrated loads along the hull. It may be a simple Gall's chain, as in some semirigids, or a very extensive structure inclosing the corridor, as in most rigids.

King-post—The main compression member of a trussing system applied to support a single member subject to bending.

Kite—An aircraft heavier than air, restrained by a tow line and sustained by the relative wind.

Kymograph—An instrument for recording the angular oscillations of an aircraft in flight with respect to axes fixed in space. The reference direction is usually given by a gyroscope or a beam of sunlight.

Landing field—A field of such a size and nature as to permit of aircraft's landing and taking off in safety. It may or may not be part of an airport.

Landing field, emergency—A locality, either of water or land, which is adapted for the landing and taking off of aircraft but which is not equipped with facilities for shelter, supply, and repair of aircraft and is not used regularly for the receipt or discharge of passengers or cargo by air.

Landing gear—The understructure which supports the weight of an aircraft when in contact with the surface of the land or water and reduces the shock on landing. There are five common types—boat type, float type, skid type, wheel type, and ski type. (Amphibian may be a combination of the float or boat type with wheels or skis.)

Landing T—A large symbol shaped like a capital T which is laid out on a landing field or on the top of a building to guide operators of aircraft in landing and taking off.

Landplane—An airplane designed to rise from and alight on the land.

Leading edge—The foremost edge of an airfoil or propeller blade. Also called "entering edge."

Leak detector—An instrument which detects the presence of hydrogen and other light gases in the air and which can be adapted to find leaks in a container inflated with such a gas.

Left side (engine)—That side which, to an observer looking from the antipropeller end toward the propeller end, lies on the left-hand side.

Lift—That component of the total air force on an aircraft or airfoil which is perpendicular to the relative wind and in the plane of symmetry. It must be specified whether this applies to a complete aircraft or to parts thereof. In the case of an airship, this is often called "dynamic lift." Its symbol is L .

The absolute lift coefficient is C_L as defined by the equation

$$C_L = \frac{L}{qS}$$

in which L is the lift, q is the impact pressure ($= \frac{1}{2}\rho V^2$), and S is the effective area of the surface upon which the air force acts.

Lift (of a gas)—The difference of density of air and the gas. Both supposed to be under the same conditions of pressure, temperature, etc.

Lift, dynamic—The lift impressed on an aerostat by aerodynamic forces.

Lift, gross (airship)—The lift obtained from a volume of buoyant gas equal to the nominal gas capacity of the aircraft. Obtained by multiplying the nominal gas capacity by the lift per unit volume of the gas used for inflation.

Lift, static (aerostat)—The resultant upward force on an aerostat at rest obtained by multiplying the actual volume of the air displaced by the density of the air and subtracting the weight of the contained gas. (The volume of the air displaced, multiplied by the difference of density of the air and the contained gas.)

Lift, useful (airship)—The lift available for carrying fuel, and oil, passengers, cargo, food, and drinking water, guns, ammunition, and bombs. Usually determined by deducting from the gross lift all fixed weights; certain allowances of ballast, fuel, and oil; water; spares and tools; crew and equipment. No standard has as yet been established.

Lift wire—See *Wire, lift*.

Line, bow-steadying—See *Line, yaw*.

Line, grab—See *Line, handling*, and *Rope drag*.

- Line, handling**—A line attached along the side of an airship for use in maneuvering near and on the ground. Sometimes called “grab line.”
- Line, main mooring**—The line dropped from the bow of an airship to be coupled to the mast main mooring line.
- Line, mast bow-steadying**—See *Line, mast yaw*.
- Line, mast main hauling**—Same as *Mast main mooring line*.
- Line, mast main mooring**—A line led from the main winch of a mooring mast through the mooring attachment at the top of the mast and carried out to a point on the ground well to leeward of the mast. The airship's main mooring line is attached to this line and the airship is hauled to the mast by means of the joined lines. Sometimes called “ground wire” (British).
- Line, mast yaw**—One of the lines led from a winch at the base of the mooring mast through snatch blocks and carried out to leeward of the mast. The airship's yaw lines are attached to these lines. The snatch blocks are fixed to anchorages selected so that the joined lines tend to keep the airship into the wind and prevent her overriding the mast. These lines are also sometimes called “mast yaw guys” or “mast bow-steadying lines.”
- Line, mooring**—A line attached near the bow of an airship for securing it to the ground or to a mooring mast.
- Line, nose-steadying**—See *Line, yaw*, which is to be preferred.
- Line, sandbag**—A rope extending along the line of suspension ropes or bridles of a kite balloon to which are hooked the sandbags used in mooring the balloon. The purpose is to prevent wear on the suspension cordage.
- Lines, control**—The lines of wire and/or stranded cable leading from the control car or compartment to the various parts of an airship and operating (either through mechanisms or directly) the rudders, valves, etc., which control the speed, altitude, etc., of the airship.
- Line, suspension**—A line either of cordage or metal, which supports the weight attached to the envelope of a balloon or airship.
- Line, yaw**—A line dropped from the bow of an airship, when mooring to the mast, to act as a steadying line to prevent yawing and overriding the mast. Also called “bow-steadying line” or “yaw guy.” (“Side guy wire”—British.)

Load :

Dead—See *Weight, empty*.

Full—Weight empty plus useful load. Also called "gross weight."

Pay—That part of the useful load from which revenue is derived, *viz.*, passengers and freight.

Useful—The crew and passengers, oil, and fuel, ballast other than emergency, ordnance, and portable equipment.

Load, basic—The load on an aircraft when it is at rest or in a condition of unaccelerated rectilinear flight. (For purposes of stress analysis.)

Load, dynamic—Any load due to accelerations of an aircraft, and therefore proportional to its mass.

Load factor—The ratio of any specified load on a member to the corresponding basic load. Generally applied to the ratio of the breaking load to a basic load.

Load ring—See *Ring, concentration*.

Loading, power—The gross weight of an airplane, fully loaded, divided by the normal brake horsepower of the engine computed for air of standard density, unless otherwise stated.

Loading, wing—The gross weight of an airplane, fully loaded, divided by the area of the supporting surface. The area used in computing the wing loading should include ailerons, but not the stabilizer and elevators.

Lobe—An air- or gas-inflated bag fitted at the stern of a kite balloon and acting as a fin or stabilizer to give it aerodynamic stability.

Logarithmic decrement—The natural logarithm of the ratio of two successive amplitudes in a damped harmonic motion. It is equal to the product λT , where λ is the coefficient appearing in the damping factor of damped harmonic motion and T is the period of the motion.

Longeron—A fore-and-aft member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support.

Longitudinal dihedral angle—See *Angle, longitudinal dihedral*.

Longitudinal, intermediate—An intermediate longitudinal strength member of a rigid airship, which lies between two adjacent main longitudinals and is generally of lighter weight and/or smaller dimension than the main longitudinals.

Longitudinal, main—A main longitudinal strength member, of a rigid airship, which connects the various transverse frames.

- Loop, mooring**—See *Loop, sandbag*.
- Loop, safety**—A loop formed in a rip cord and attached to a securing patch by a breakable cord or a spring clip. It may be formed either inside the envelope and close to the rip panel or outside the envelope near the gland by which the rip cord passes through the envelope. Before the rip panel can be "pulled," the breakable cord must be broken or the clip opened. Accidental "pulling" is thus made unlikely, as the weight of the cord is easily carried by the breakable cord or spring clip.
- Loop, sandbag**—A system of cordage loops on the envelope of a balloon for suspending sandbags. See also *Line, sandbag*.
- Main hauling line**—See *Line, main mooring*.
- Maneuverability**—That quality in an aircraft which makes it possible for the pilot to change its attitude rapidly.
- Manhole, appendix**—An appendix of large diameter and usually rather short. It is used more for access than for inflation or deflation.
- Manifold, inflation**—A metal or fabric connection with numerous inlets which permits the passage of gas at the same time from a number of sources (either cylinders or gas holders) to the main inflation tube.
- Mast bow-steadying line**—See *Lines, mast yaw*.
- Mast, mooring**—A mast or tower at the top of which there is mounted a fitting, so that the bow of an airship may be secured. It is usually provided with a ladder or staircase and a platform at the top, so that crew and passengers may enter or leave the airship, and also with piping for the supply of fuel, gas, and water. Sometimes called "mooring tower."
- Meter, air-speed**—See *Air-speed meter*.
- Meter, ground-speed**—See *Ground-speed meter*.
- Meter, superheat**—An instrument for measuring the difference in temperature between the gas in a gas container of a lighter-than-air craft and the surrounding air.
- Monoplane**—An airplane which has but one main supporting surface, sometimes divided into two parts by the fuselage.
- Mooring, three-point**—A system of mooring an airship. It consists primarily of three lines running from a mooring ring (or point) on the airship to three points on the ground. These points are usually at the vertices of an equilateral triangle. The lines may be secured to anchorages at the points, or run over snatch blocks and to

equalizing gear. The endeavor is to moor the airship in such a manner that the dynamic lift, due to the relative wind, shall keep the airship at a constant height from the ground. May be considered as a substitute for a mooring mast, usually an emergency substitute.

Mooring tower—See *Mast, mooring*.

Multiplane—An airplane with two or more main supporting surfaces placed one above another.

Nacelle—An inclosed shelter for passengers or for a power plant. A nacelle is usually shorter than a fuselage and does not carry the tail unit.

Net:

Free-balloon—A rigging made of ropes and twine shaped to the upper surface of the envelope, which supports the weight of the basket, etc., and distributes the load over the entire upper surface of the envelope.

Gas-cell (rigid airship)—A netting of cord of small mesh which is intended to assist the fabric of the gas cells in transmitting gas force to a wire netting of coarser mesh and to the longitudinals, both being fitted between the longitudinals. It may be compared to the net of a free balloon. Sometimes called "gas-cell netting" or "cord netting."

Inflation—A rectangular net of cordage used to restrain the envelope of a kite balloon or airship during inflation. Also applied to a free-balloon net designed to be removed after inflation.

Netting cord—See *Net, gas cell (rigid airship)*.

Nose (airship)—Sometimes used for bow.

Nose batten—See *Stiffener, bow*.

Nose cap—See *Cap, bow*, which is to be preferred.

Nose-heavy—The condition of an airplane in normal flight when the distribution of forces is such that, if the longitudinal controls were released, the nose would drop.

Nose-heavy (airship)—See *Bow-heavy*.

Nose-steady line—See *Line, yaw*.

Nozzle, pressure—An instrument which, in combination with a gage, is used to measure the indicated speed of an aircraft relative to the air. It may be a Pitot-static or a Venturi tube, or a combination of a Pitot tube and a Venturi tube.

Nurse balloon—See *Balloon, constant pressure*.

Nursing tube—See *Tube, supply*.

Ornithopter—A form of aircraft heavier than air, deriving its chief support and propelling force from flapping wings.

Oscillation, phugoid—A long-period oscillation characteristic of the disturbed longitudinal motion of an aircraft. This is referred to when it is said that an aircraft "hunts."

Oscillation, stable—An oscillation whose amplitude does not increase.

Oscillation, unstable—An oscillation whose amplitude increases continuously until an attitude is reached from which there is no tendency to return toward the original attitude, the motion becoming a steady divergence.

Outrigger, mooring-cone—The member, usually tubular, which supports the mooring cone at the bow of the airship. Sometimes referred to as "mooring spindle."

Over-all length—The distance from the extreme front to the extreme rear of an aircraft, including the propeller and the tail unit.

Overhang—Used in two senses. (1) One-half of the difference in span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (2) The distance from the outer strut attachment to the tip of the wings.

Pancake, to—To level off an airplane at a greater altitude than normal in a landing, thus causing it to stall and to descend on a steeply inclined path with the wings at a very large angle of attack and without appreciable bank.

Panel (aerostat)—The unit piece of fabric of which the envelope or outer cover of an aerostat is made. Panels may be assembled into sections, gores, or rings, according to the method of manufacture followed.

In rigid airships the area bounded by two adjacent longitudinals and two adjacent transverses is often referred to as a "panel." This is a structural panel, and the expression is borrowed from structural engineers.

Panel, rip—A strip of fabric inserted or fitted in the upper part of the envelope of a balloon or semirigid or non-rigid airship which is torn or ripped open when immediate deflation is desired.

Panel (wing parts)—Where a wing surface comprises several units of construction, these units are designated as panels.

Parasite resistance—See *Drag*.

Patch—A strengthened or reinforced flap or fabric of special shape and construction, which is cemented to the envelope or gas cell. It usually forms an anchor by which some portion of the structure may be attached to the envelope, or by which the positioning lines controlling the gas cell may be attached to the cell.

Patch, chafing—A patch of fabric secured to an envelope of an aerostat to protect it from abrasion.

Patch, channel—A channel-shaped fabric-fitting secured to the envelope of an aerostat to allow a rod or spar to be laced to the envelope.

Patch, finger—A special form of patch having extensions or “fingers” extending out from the central portion. The “fingers” may be of tape, frayed-out rope, or fabric. Their function is to distribute the load more widely to the fabric of the envelope or gas cells.

Patch, suspension—A patch, secured to the envelope or to a gas cell of an aerostat, to which a suspension line may be attached.

Pendant, sighting—A vertical wire on center-line and forward of the control car of an airship, used as a mark in steering, to assist in determining wind direction.

Period—The time taken for a complete oscillation.

Permeability—The measure of the rate of diffusion of gas through intact balloon fabric; usually expressed in liters of hydrogen per square meter of fabric per 24 hours, under standard conditions of pressure and temperature.

Pilot—An operator of aircraft. This term is applied regardless of the sex of the operator.

Pitch of a propeller:

Effective—The distance which an aircraft advances along its flight path for one revolution of the propeller. Its symbol is p_e .

Geometrical—The distance which an element of a propeller would advance in one revolution, if it were moving along a helix of slope equal to its blade angle.

Mean geometrical—The mean of the geometrical pitches of the several elements. Its symbol is p_g .

Standard—The geometrical pitch taken at two-thirds of the radius. Also called “nominal pitch.” Its symbol is p_s .

- Zero thrust**—The distance which a propeller would have to advance in one revolution in order that there might be no thrust. Also called "experimental mean pitch." Its symbol is p_r .
- Zero torque**—The distance which a propeller would have to advance one revolution in order that the torque might be zero. Its symbol is p_a .
- Pitch ratio**—The ratio of the pitch (geometrical, unless otherwise stated) to the diameter p/D .
- Pitch speed**—The product of the mean geometrical pitch by the number of revolutions of the propeller in unit time, *i.e.*, the speed the aircraft would make if there were no slip.
- Pitot tube**—A cylindrical tube with an open end which is pointed upstream (*i.e.*, so that the air meets the instrument head-on or is met head-on by the instrument). When the aircraft is flying less than about 200 miles per hour, the instrument measures the impact pressure. When used on aircraft, it is usually associated either with a closed coaxial tube surrounding it or with a closed tube placed near it and parallel to it, the combination being termed a Pitot-static tube. The associated tube has perforations in its side so that it is subjected to static pressure, as distinct from impact pressure. The speed of the fluid can be determined from the difference between the impact pressure and the static pressure, as read by a suitable gage. In common terminology, the Pitot-static combination, as above, is often termed simply a Pitot tube or Pitot.
- Platform, observation**—A platform or small deck fitted on the top of an airship and used as a post for a lookout and defense or as a place from which to make observations used in navigating the airship.
- Plywood**—A product formed by gluing together two or more layers of veneer. The alternate plies are usually placed with grain at right angles to the adjacent plies.
- Pontoon (now obsolete)**—See *Float*.
- Pressure alarm**—See *Alarm, gas-cell*.
- Pressure, dynamic**—See *Dynamic (or impact) pressure*.
- Pressure, manometer (aerostat)**—The excess of pressure inside the envelope of an aerostat over the atmospheric pressure at a standard reference point. The point of reference for the excess of pressure is usually the bottom of the envelope or gas cell for airships and the level of the basket for kite balloons.

Pressure-tube gland—See *Gland, manometer-tube*.

Profile—See *Airfoil section (or profile)*.

Profile drag—See *Drag*.

Proofing—Material incorporated in the fabric of an aerostat at the time of manufacture to increase its resistance to the weather and/or to prevent the passage of gas (or decrease its permeability).

Propeller:

Adjustable pitch—A propeller whose blades are so attached to the hub that they may be set to any desired pitch when the propeller is stationary.

Controllable pitch or variable pitch—A propeller whose blades are so mounted that they may be turned about their axis to any desired pitch while the propeller is in rotation.

Propeller area, projected—The total area in the plane perpendicular to the propeller shaft swept by the propeller, excepting the portion covered by the boss and that swept by the root of the blade. This portion is usually taken as extending 0.2 of the maximum radius from the axis of the shaft.

Propeller blade—See *Blade face; blade back; blade-width ratio*.

Propeller-blade area—The area of the blade face, exclusive of the boss and the root, *i.e.*, of a portion which is usually taken as extending 0.2 of the maximum radius from the axis of the shaft.

Propeller boss—The central portion of a propeller in which the hub is formed or mounted.

Propeller-camber ratio—The ratio of the maximum thickness of a propeller section to its chord.

Propeller-disk area, total—The total area swept by a propeller, *i.e.*, the area of a circle having a diameter equal to the propeller diameter.

Propeller efficiency—The ratio of thrust power to power input of a propeller. Its symbol is η .

Propeller hub—The metal fitting inserted or incorporated in or with a propeller for the purpose of mounting it on the propeller or engine shaft.

Propeller interference—The amount by which the torque and thrust of a propeller are changed by the modification of the air flow in the slip stream produced by bodies placed near the propeller, such as engine, radiator, etc.

- Propeller-load curve**—A curve representing the engine power necessary to drive any given propeller at various speeds. The power required varies approximately as the cube of the speed in r.p.m., provided the ratio $\frac{V}{ND}$ remains constant.
- Propeller, pusher**—A propeller mounted to the rear of the engine or propeller shaft. (It is usually behind the wing cell or nacelle.)
- Propeller rake**—The mean angle which the line joining the centroids of the sections of a propeller blade makes with a plane perpendicular to the axis.
- Propeller root**—That part of the propeller blade near the boss.
- Propeller section**—A cross-section of a propeller blade made at any point by a plane parallel to the axis of rotation of the propeller and tangent at the centroid of the section to an arc drawn with the axis of rotation as its center.
- Propeller thrust**—The component parallel to the propeller axis of the total air force on the propeller. Its symbol is T .
- Propeller torque**—The moment applied to the propeller by the engine shaft. Its symbol is Q .
- Propeller, tractor**—A propeller mounted on the forward end of the engine or propeller shaft. (It is usually forward of the fuselage or wing nacelle.)
- Propeller-width ratio, total**—The product of blade-width ratio at the point of maximum blade width by number of blades.
- Propulsive efficiency**—The ratio of the product of effective thrust and flight speed to the actual power input to the propeller as mounted on the airplane, consistent units being used throughout.
- Purity (of gas)**—The ratio of the pressure of the hydrogen (or other aerostatic gas) in the container to the total pressure due to all the contained gases.
- Pusher airplane**—See *airplane, pusher*.
- Quadrant**—The operating lever, made on the arc of a circle, of a control surface of an airship, *e.g.*, rudder quadrant, elevator quadrant.
- Quadruplane**—An airplane with four main supporting surfaces, placed one above another.
- Race rotation**—The rotation, produced by the action of the propeller, of the stream of air passing through or influenced by the propeller.

Rail, docking—A rail or guide, constructed on the landing field and extending into the shed, which supplies a means for holding the lateral pull of an airship's docking or handling lines. The pull is transmitted to the rails from wheeled cars or trolleys which are fitted on or in the rails. Usually two rails are fitted at the greatest distance apart which will permit them to be run into the shed.

Rake, propeller—See *Propeller rake*.

Ram—The combination of tubes and springs which is mounted in gimbals at the top of a mooring mast. It consists of an outer tube which carries the gimbal mounting and within which slides an inner tube. The upper end of the inner tube carries the hollow cone which receives the airship's mooring cone and which is fitted to revolve freely. The inner tube can slide down into the outer tube and compress heavy springs, thus easing the shock when the mooring is made.

Range at economic speed—The maximum distance a given aircraft can cover while cruising at the most economical speed and altitude at all stages of the flight.

Range at full speed—The maximum distance a given aircraft can cover at full speed at sea level.

Rate of climb—The vertical component of the air speed of an aircraft, *i.e.*, its vertical velocity with reference to the air.

Recorder, flight—An instrument for recording certain elements of the performance of an aircraft.

Resistance derivatives—Quantities expressing the variation of the forces and moments on aircraft due to disturbance of steady motion. They form the experimental basis of the theory of stability, and from them the periods and damping factors of aircraft can be calculated. In the general case, there are 18 translatory and 18 rotary derivatives.

Lateral—Resistance derivatives expressing the variation of moments and forces due to small changes in the lateral, yawing, and rolling velocities.

Longitudinal—Resistance derivatives expressing the variation of moments and forces due to small changes in the longitudinal, normal, and pitching velocities.

Rotary—Resistance derivatives expressing the variation of moments and forces due to small changes in the rotational velocities of the aircraft.

Translatory—Resistance derivatives expressing the variation of moments and forces due to small changes in the translational velocities of the aircraft.

Restoring moment—See *Righting moment*.

Revolutions, maximum—The number of revolutions per minute corresponding to the maximum horsepower.

Revolutions, rated—The number of revolutions corresponding to the rated horsepower.

Reynolds Number—A name given the fraction $\rho \frac{Vl}{\mu}$ in which

ρ is the density of the fluid,

V is the relative velocity of the fluid;

l is the linear dimension of the body;

μ is the coefficient of viscosity of the fluid.

Rigger—One who is employed in assembling and aligning aircraft.

Rigging (aerostat)—The attachment and adjustment of the car, rudders, valves, controls, etc., of an airship.

Rigging (airplane)—The assembling, adjusting, and aligning of the parts of an airplane.

Righting moment (or restoring moment)—A moment which tends to restore an aircraft to its previous attitude after any small rotational displacement.

Right side (engine)—That side which, to an observer looking from the antipropeller end toward the propeller end, lies on the right-hand side.

Ring, concentration :

Airship—A ring to which several rigging lines are led from the envelope and from which one or more lines also lead to the car.

Free balloon—A ring to which are attached the ropes suspending the basket and to which the net is also secured. Sometimes called "load ring."

Ring, load—See *Ring concentration (free balloon)*.

Ring, mooring—A metallic ring suspended from one of the forward frames of a rigid airship by wire lines and used for mooring. The vertex of a "three-point mooring" is attached to this ring.

Roll—A maneuver in which a complete revolution about the longitudinal axis is made, the horizontal direction of flight being approximately maintained.

- Rope, drag**—A long rope which can be hung overboard from a balloon so as to act as a brake and a variable ballast in making a landing. Same as "trail rope" or "guide rope." On airships a similar rope or ropes is used as a haul-down or mooring line by the landing crew. It is usually larger and longer than a regular handling line. Sometimes called "grab line."
- Rope, mooring**—A line attached to a balloon or airship for use in securing it to the ground. It may serve the purpose of a "handling line," or vice versa.
- Rope, trail**—See *Rope, drag*.
- Rudder**—A movable auxiliary airfoil, the function of which is to impress a yawing moment on the aircraft in normal flight. It is usually located at the rear of an aircraft.
- Rudder (airship)**—A hinged or pivoted surface, usually attached to a fin at the after end of an airship. When operated by the pilot, it produces a yawing moment and gives directional control in the plane at right angles to the axis about which it is hinged or pivoted.
- Rudder bar**—The foot bar by means of which the control cables leading to the rudder are operated.
- Rudder torque**—The twisting moment exerted by the rudder on the fuselage. The product of the rudder area by the distance from its center of area to the axis of the fuselage may be used as a relative measure of rudder torque.
- Sag**—A distortion of an airship in which the longitudinal axis becomes concave upward so that both ends rise.
- Seaplane**—Any airplane designed to rise from and alight on the water. This general term applies to both boat and float types, though the boat type is usually designated as a "flying boat."
- Shaft, climbing**—An access shaft fitted with a ladder and leading from the bottom to the top of an airship hull. This may be fitted in an airship of any type.
- Shaft, gas**—A duct or shaft leading from the bottom of the gas cells to the outer cover of an airship. It affords a clear passage for the escape of gases which have accumulated in the gangway or corridor or which are discharged from the valves at the bottom of the cells. It usually consists of light wooden hoops or frames spaced at intervals on cords or wires and is covered by a netting. It prevents the

gas cells from closing hard against one another and thus keeps the passage open. Sometimes called "gas trunk," "exhaust-gas shaft," or "trunk."

In view of the possibility of confusion with parts of an engine-exhaust system, it is believed that "gas shaft" or "trunk" is to be preferred.

Sheathing—See *Tipping (propeller)*.

Shed—A shelter for housing airships.

Ship—Slang for an airplane. In view of the confusion with "airship," it should not be used.

Shipplane—A landplane designed to rise from and alight on the deck of a ship.

Shock absorber—A device incorporated in the landing gear of an aircraft to reduce the shock imposed on the structure when alighting or taking off.

Shock-absorbing devices are usually interposed between the main structure and the wheels, floats, skis, or tail skids, to secure resiliency in landing and taxiing.

Shore—A structural member for supporting the structure of a rigid or semirigid airship during building or docking, used in conjunction with (or without) a cradle.

Side car—See *Car, wing*.

Side slipping—Flight in which the lateral axis is inclined and the airplane has a component of velocity in the direction of the lower end of the lateral axis. When it occurs in connection with a turn, it is the opposite of skidding, *q.v.*

Skid—A runner used as a member of the landing gear and designed to aid the aircraft in landing or taxiing.

Tail skid—A skid used to support the tail when in contact with the ground.

Wing skid—A skid placed near the wing tip and designed to protect the wing from contact with the ground.

Skidding—Sliding sidewise away from the center of curvature when turning. It is usually caused by banking insufficiently, and is the opposite of side slipping, *q.v.*

Skid fin—A fore-and-aft vertical surface, usually placed above the upper wing, designed to provide vertical keel surface and so to increase lateral stability.

- Skin friction**—The tangential component of the fluid force at a point on a surface.
- Sky writing**—The act of emitting from an aircraft a trail of smoke or other visible substance, the flight of the aircraft being so directed as to cause the trail to assume the form of letters or symbols.
- Sleeve, conical**—A cone-shaped fabric, fitting in a bag or cell through which a line passes. It provides a gas-tight connection of the bag or cell to the line and yet permits both some degree of freedom to move.
- Sleeve, deflation**—Generally a sleeve or appendix made of fabric provided for the special purpose of facilitating the deflation of an aerostat. Also applied to the sleeve or appendix fitted in the lower lobe of a kite balloon and used to permit the rapid escape of air in the lobes when the balloon is hauled down.
- Sleeve, filling**—See *Sleeve, inflation*.
- Sleeve, inflation (or sleeve, filling)**—A tubular fabric attachment to an envelope or gas bag, serving as a lead for the inflation tube.
- Slip**—The difference between the mean geometrical pitch and the effective pitch. Slip may be expressed as a percentage of the mean geometrical pitch or as a linear dimension.
- Slip function**—The ratio of speed of advance through the undisturbed air to the product of propeller diameter by the number of revolutions in unit time, *i.e.*, $\frac{V}{ND}$. The slip function is the primary factor controlling propeller performance. It is π times the ratio of forward speed to the tip speed of the propeller.
- Slip stream**—The stream of air driven astern by the propeller. (The indraft is sometimes included, also.)
- Snatch-block anchorage**—See *Anchorage, snatch block*.
- Soar**—To perform sustained free flight without self-propulsion; it is called “up-current soaring” if performed in ascending air; “dynamic soaring” in other cases.
- Sounding balloon**—See *Balloon, sounding*.
- Sound-ranging altimeter**—See *Altimeter, sound-ranging*.
- Span (airfoil)**—The lateral dimension of an airfoil, *i.e.*, its dimension perpendicular to its chord. Its symbol is *b*.
- Span (airplane)**—The maximum distance measured parallel to the lateral axis from tip to tip of an airplane inclusive of ailerons.
- Spar**—See *Wing spar*.

- Speed, critical**—The lowest speed of an aircraft at which control can be maintained.
- Speed, economic**—The speed at which the fuel consumption, per unit of distance covered in still air, is a minimum.
- Speed, ground**—The horizontal component of the velocity of an aircraft relative to the earth.
- Speed, landing**—The minimum speed at which an airplane can maintain itself in level flight and still be under adequate control.
- Speed, minimum**—The lowest steady speed which can be maintained by an airplane in level flight at an altitude large in comparison with the dimensions of the wings, with any throttle setting whatever.
- Spin**—A maneuver consisting of a combination of roll and yaw, with the longitudinal axis of the airplane inclined steeply downward. The airplane descends in a helix of large pitch and very small radius, the upper side of the airplane being on the inside of the helix, and the angle of attack on the inner wing being maintained at an extremely large value.
- Spindle, mooring**—See *Outrigger, mooring cone*.
- Spinner**—A fairing of approximately conical or paraboloidal form, which is fitted coaxially with the propeller boss and revolves with the propeller.
- Spiral**—A maneuver in which an airplane descends in a helix of small pitch and large radius, the angle of attack being within the normal range of flight angles.
- Spiral instability**—See *Stability*.
- Stability**—That property of a body which causes it, when disturbed from a condition of equilibrium or steady motion, to develop forces or moments which tend to restore the body to its original condition.
- Automatic**—Stability dependent upon movable control surfaces automatically operated by mechanical means.
- Inherent**—Stability of an aircraft due solely to the disposition and arrangement of its fixed parts, *i.e.*, that property which causes it, when disturbed, to return to its normal attitude of flight without the use of controls or the interposition of any mechanical devices.
- Statio**—Stability of such a character that, if the airplane is displaced slightly from its normal attitude by rotation about an axis through its center of gravity (as may be done in wind-tunnel experiments),

moments come into play which tend to return the airplane toward its original attitude.

Dynamic—Stability of such a character that, if the airplane is displaced from steady motion in flight, it tends to return to that steady state of motion, the oscillations due to restoring moments being damped out.

In a general way, the difference between static stability and dynamic stability is that the former depends on restoring moments alone, while the latter includes the action of damping factors.

Longitudinal—Stability with reference to disturbances in the plane of symmetry, *i.e.*, disturbances involving pitching and variation of the longitudinal and normal velocities.

Directional—Stability with reference to rotations about the normal axis, *i.e.*, an airplane possesses directional stability in its simplest form if a restoring moment comes into action when it is given a small angle of yaw. Owing to symmetry, directional stability is closely associated with lateral stability.

Lateral—Stability with reference to disturbances involving rolling, yawing, or side slipping, *i.e.*, disturbances in which the position of the plane of symmetry of the aircraft is affected.

Spiral instability—A type of instability inherent in certain airplanes which becomes evident when the airplane, as a result of a yaw, assumes too great a bank and side slips; the bank continues to increase and the radius of the turn to decrease.

Stabilizer—A normally fixed airfoil whose function is to lessen the pitching motion. It is usually located at the rear of an aircraft and is approximately parallel to the plane of the longitudinal and lateral axes. Also called "tail plane."

Stabilizer (aerostat)—Same as *F_{in}*. The lobes of a kite balloon are sometimes referred to as stabilizers.

Stabilizer, mechanical—A mechanical device to prevent an aircraft from departing from a condition of steady motion, or, in case such a motion is disturbed, to restore it to its steady state. Includes gyroscopic stabilizers, pendulum stabilizers, inertia stabilizers, etc.

Stabilizer setting, angle of—See *Angle of stabilizer setting*.

Stable oscillation—See *Oscillation, stable*.

Stagger—The amount of advance of the leading edge of one wing of a biplane, triplane, or mutliplane over that of the other, expressed

either as a percentage of gap or in degrees of the angle whose tangent is the percentage just referred to. It is considered positive when the upper wing is forward and is measured from the leading edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the leading edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry.

Stall—The condition of an airplane when from any cause it has lost the air speed necessary for support or control.

Station, airship—The complete assembly of sheds, masts, gas plants, shops, landing fields, and related equipment required to operate airships and supply their needs. A station may include all or a part of the items enumerated. The base from which airships are operated.

Statoscope—An instrument for detecting minute changes of altitude of an aircraft. The indications of the instrument usually depend on small changes of the static pressure of the air.

Stay—A wire or other tension member; for example, the stays of the wing and body trussing.

Step—A break in the form of the bottom of a float or hull designed to reduce resistance when under way by rapidly reducing the wetted surfaces as speed increases. It also serves to eliminate suction effects.

Stern-droop—A deformation of an airship in which its longitudinal axis bends downward at the after end.

Stern-heavy—The condition in which, in normal flight, the after end of an airship tends to sink and which requires correction by means of the horizontal controls. In this condition, an airship is said to "trim by the stern." It may be due to either aerodynamic or static conditions, or to both.

Stiffener, bow—A rigid member attached to the bow of a non-rigid or semirigid envelope to reinforce it against the pressure caused by the motion of the airship. Sometimes called "nose stiffener" or "nose batten."

Streamline—The path of a small portion of a fluid relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such flows as are not eddying, but the distinction should be made clear by the context.

- Streamline flow**—Steady flow past a solid body, *i.e.*, a flow in which the direction at every point is independent of time.
- Streamline form**—A solid body which produces approximately streamline flow.
- Stresses, breathing**—Stresses produced in an aerostat by breathing. Of importance in the envelope and keel of a semirigid airship due to the interaction of envelope and keel when the envelope "breathes."
- Strip, drip**—See *Flap, drip*.
- Structural drag**—See *Drag*.
- Strut**—A compression member of a truss frame. For instance, the vertical members of the wing truss of a biplane (interplane struts) and the short vertical and horizontal members separating the longerons, *q.v.*, in the fuselage.
- Strut, drag**—A fore-and-aft compression member of the internal bracing system of a wing.
- Supercharger**—A mechanical device for supplying the engine with a greater weight of charge than would normally be induced at the prevailing atmospheric pressure and temperature.
- Centrifugal type**—A supercharging device equipped with one or more rotating impellers generating centrifugal force which is utilized for the compression and the transmission of the air against resistance.
- Positive-driven type**—A supercharger driven at a fixed-speed ratio from the engine shaft by gears or other positive means.
- Rotary-blower type**—A supercharging device comprising one or more relatively slow-speed rotors revolving in a stationary case in such a way as to provide a positive displacement.
- Turbo type**—A supercharger driven by a turbine operated by the exhaust gases from the engine.
- Superheat**—The amount by which the temperature of the gas in the envelope or gas cells of an aerostat is higher than the temperature of the surrounding air. If the contained gas has a lower temperature, the superheat is said to be negative.
- Surface, control**—A movable airfoil designed to be rotated or otherwise moved by the pilot in order to change the attitude of the airplane or airship.
- Surface, fixed**—See *Fin*.

- Surface, main supporting**—A set of wings, extending on the same general level from tip to tip of an airplane; *e.g.*, a triplane has three main supporting surfaces. The main supporting surfaces include the ailerons, but no other surfaces intended primarily for control or stabilizing purposes.
- Suspension, overhead**—A line leading from the roof of an airship shed and arranged to sustain the whole or a part of the weight of the structure of an airship when it is docked.
- Suspension winch**—The rigging by means of which the lift and drag of a kite balloon is transmitted from the envelope to the towing or traction cable.
- Sweep back**—The acute angle between the lateral axis of an airplane and the projection of the axis of the wing on the plane which includes the lateral and longitudinal axes. (The axis of a wing is a line through the centroids of the section of the wing.)
- Tachometer**—Instrument for measuring r.p.m.'s. engine.
- Tail (airship)**—Sometimes used for stern.
- Tail boom**—A spar or outrigger connecting the tail surfaces and main supporting surfaces.
- Tail-droop**—See *Stern-droop*.
- Tail group (or tail unit)**—The stabilizing and control surfaces at the rear end of an aircraft, including stabilizer, fin, rudder, and elevator. Also called "empennage."
- Tail-heavy**—In a heavier-than-air craft, the condition in which in normal flight, the tail sinks if the longitudinal control is released, *i.e.*, the condition in which the pilot has to exert a push on the control stick to keep the given attitude.
- Tail-heavy (airship)**—See *Stern-heavy*.
- Tail plane**—See *Stabilizer*.
- Tail skid**—See *Skid*.
- Tail slide**—The backward and downward motion, tail first, which certain airplanes may be made to take momentarily after having been brought into a stalling position by a steep climb.
- Tank, fixed fuel**—A fuel tank which is not intended or fitted to be dropped, as "slip" tanks are.
- Tank, service**—A fixed fuel tank near each power unit, into which fuel from other tanks is pumped and from which the fuel supplying the engines is drawn.

- Tank, slip fuel**—A fuel tank which is provided with a device permitting the quick dropping of the tank and contents as a whole in case of an emergency. Fitted on both airships and airplanes.
- Taxi**—To run an airplane over the ground, or a seaplane on the surface of water, under its own power.
- Testing, performance**—The process of determining performance characteristics.
- Thermograph**—An instrument for recording temperature.
- Thimble**—A grooved ring of circular-, pear-, or heart-shaped form, generally of metal, which is inserted in the eye of a rope or wire to prevent chafing or deformation of the eye.
- Thrust, effective**—The net driving force delivered by a propeller when mounted on an airplane, *i.e.*, the actual thrust given by the propeller, as mounted on the airplane, minus any increase of resistance of the airplane produced by the action of the propeller.
- Thrust face**—See *Blade face*.
- Thrust, static**—The thrust developed by a propeller when rotating at a fixed point.
- Tipping (propeller)**—A sheet-metal (or equivalent) protective covering of the blade of a propeller near the tip, extended a short distance along the trailing edge and a considerable distance along the leading edge.
- Toggle**—A short cross-bar of wood or metal which is fitted at the end of a rope. The rope passes around the midlength of the bar in a shouldered groove. By slipping it through an eye in the end of another rope, the two lengths of rope can be quickly connected or disconnected.
- Topping up**—The operation of filling up with gas an already partially full aerostat. Also applied to a similar operation with fuel tanks. Incorrectly called "nursing."
- Tower, mooring**—See *Mast, mooring*.
- Tractor airplane**—See *Airplane, tractor*.
- Trailing edge**—The rearmost edge of an airfoil or propeller blade.
- Trail rope**—See *Rope, drag*.
- Trajectory band**—See *Band, trajectory*.
- Transverse, intermediate**—An open, unbraced transverse frame of a rigid airship which lies between two main or braced transverse frames.

Transverse, main—A main transverse strengthening frame of a rigid airship provided with wire or girder bracing and spaced at regular intervals throughout the length of the airship.

Trapeze bar—See *Bar, suspension*.

Trim—The attitude of an aerostat relative to a fore-and-aft horizontal plane. If the forward end is down, the aerostat is said to have "trim by the bow;" if the after end, it has "trim by the stern."

Trim, to—To alter the attitude of an aerostat relative to a fore-and-aft horizontal plane. If the endeavor is to force the bow down, the aircraft is "trimmed by the bow;" if the stern, it is "trimmed by the stern." If the aircraft shows a tendency to sink by the bow end, it is said to "trim by the bow" or to be "bow-heavy;" if the tendency is to sink by the stern, it is said to "trim by the stern" or to be "stern-heavy."

Trim, dynamic—Trim (or trimming) due to dynamic conditions or their change.

Trim, static—Trim (or trimming) due to static conditions or their change.

Triplane—An airplane with three main supporting surfaces, placed one above another.

Trolley, docking—A car or trolley fitted on (or in) docking rails to transmit the pull of an airship docking line. It is fitted with wheels having antifriction bearings so it can move freely in the rail. Usually some sort of quick-release device for letting go the line is also fitted.

Tube, inflation—A fabric tube leading from the inflation manifold or source of supply to the inflation sleeve of the gas cell or envelope.

Tube, nursing—See *Tube, supply*.

Tube, pressure—A tube fitted to an envelope or gas bag, to which a pressure gage may be attached.

Tube, supply—An elongated appendix or inflation sleeve, fitted on a kite balloon, which is brought down to the basket and fitted with a quick-connection coupling. This coupling can be attached to a similar piece on the deck of the airship and gas may be sent into the balloon shortly after it has reached the deck. A similar tube is sometimes used with airships where constant-pressure nurse balloons are used. This is rare in the United States. Also called "nursing tube."

Turn indicator—See *Indicator, turn*.

Turn, reverse—A rapid maneuver to reverse the direction of flight of an airplane, made by a half loop and half roll.

Valve, automatic—A spring-loaded relief valve fitted to the envelope, ballonet, or gas cell of an aerostat and set to open at a predetermined pressure for the purpose of preventing excessive internal pressure.

Also applied to a type of valve used on some aerostats which opens at a predetermined contained volume or hull dimension.

Valve cover—See *Hood, valve*.

Valve, maneuvering—A manually operated valve fitted to the envelope, ballonet, or gas cell of an aerostat for the purpose of releasing gas or air from within the envelope or gas cell when desired.

Valve petticoat—A special sleeve between valve and gas container, making it possible to tie off the sleeve and change valves without loss of gas.

Valve seal—A fabric cover used to seal the automatic valves of a rigid airship when docked in the shed. “Jam-pot cover” (British).

Veneer—Thin sheets of wood, either sliced with a knife or sawed.

Vent, pressure-relief—A small opening in the covering of the fin of an airship intended to facilitate the equalization of the pressure of the air within the fin with that of the outside air. It also provides an outlet for any gas that may collect in the fin.

Venturi, power—A Venturi tube used to operate gyroscopic turn indicators and other instruments.

Venturi, speed-indicating—A Venturi tube may be combined with a Pitot tube or with a tube giving static pressure to form a pressure nozzle which may be used to determine the indicated speed of an aircraft through the air. The pressure difference is measured by a suitable gage.

Venturi tube—A short tube with flaring ends and a narrow or constricted section between them, into which a side tube opens. When fluid flows through the Venturi, there is a reduction of pressure in the constricted section, the amount of the reduction being a function of the velocity of flow.

Vertimeter—A device for indicating the rate of rise and fall of an aerostat, usually a special form of statoscope. A rate-of-climb meter serves the same purpose, although of a different form.

Volume—The volume of the air displaced by the gas used for inflation.

Volume, aerodynamic (airship)—The volume of the form which must be driven through the air. Same as "air volume."

Volume, air (airship)—The volume of air displaced by the body formed by the outer cover or envelope of an airship. It is this volume which enters into aerodynamic computations. See *Volume, aerodynamic (airship)*.

Volume, gas (airship)—The volume of the contained gas. See *Capacity*.

V-wires—The lower lines of the winch suspension of the kite balloon. They meet at the junction piece and form V's; hence the name.

Warp—To change the form of a wing by twisting it. Warping is sometimes used to maintain the lateral equilibrium of an airplane.

Wash—The disturbance in the air produced by the passage of an airfoil. Also called the "wake" in the general case for any solid body.

Washin—Permanent warping of the wing which results in an increase in the angle of attack near the tip.

Washout—Permanent warping of a wing which results in a decrease in the angle of attack near the tip.

Weight, dischargeable (consumable weight) (airship)—All weight which can be consumed or discharged and still leave the airship in safe operating condition with a specified reserve of fuel, oil, water ballast, and provisions, and her normal crew.

Weight, disposable (airship)—All weight other than fixed weights, including dischargeable weights contrasted with fixed weights, *q. v.*

Weight, empty—The structure, power plant, and fixed equipment of an aircraft. Included in this fixed equipment are the water in the radiator and cooling system, all essential instruments and furnishings, fixed electric wiring for lighting, heating, etc. In the case of the aerostat, the amount of ballast which must be carried to assist in making a safe landing must also be included.

Weight, fixed (airship)—The weight of the hull machinery and all equipment and parts which are fixed in position and non-consumable. All constant and non-consumable weights which an airship would carry under all conditions of service (British). Liquids in cooling systems of engines are included.

Weight, fixed power-plant, for a given airplane—The weight of an engine, including ignition, carbureter, and induction systems

complete, propeller and hub, exhaust manifolds, radiator, and water, *if used*, with all interconnecting wires, controls, tanks, and pipes, lubricating-oil temperature regulators, *the oil contained in the engine crankcase*, and the starting gear attached to the engine, but excluding fuel, oil, and engine instruments.

Weight per horsepower—The dry weight of an engine divided by the rated horsepower.

Windmill—An air-driven screw used to drive auxiliary apparatus on an aircraft.

Window, inspection—A small transparent window fitted in the envelope of a balloon or airship, or in the wing of an airplane, to allow inspection of the interior.

Wind, relative—The motion of the air with reference to a body, *i.e.*, its motions as observed by a man at rest on the body. The direction and velocity of the relative wind, therefore, are found by adding two vectors, one being the velocity of the air with reference to the earth, the other being equal and opposite to the velocity of the body with reference to the earth.

Wind tunnel—An elongated chamber, usually a tube divergent at the ends, through which a steady air stream may be drawn or forced. Models of airfoils, of aircraft, or of propellers may be placed in the middle portion of the tunnel, called the experiment chamber or working section, and supported by suitable balances placed outside the air stream, so that the forces, moments, etc., due to the moving air may be measured.

Wing—A general term applied to a whole or a portion of the main supporting surfaces of an airplane, but in the latter case is usually qualified as right wing, left wing, upper wing, or lower wing, etc.

Wing car—See *Car, wing*.

Wing drag—See *Drag*.

Wing-heavy—The condition of an airplane in which (in normal flight) there is a tendency for the right (or left) wing to drop, if the lateral control is released, *i.e.*, the condition in which the pilot has to exert a lateral force on the control stick to keep the lateral axis horizontal.

Wing rib—A fore-and-aft member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars.

Rib compression—A heavy rib designed to have the function of a wing rib and also to act as a strut opposing the pull of the wires in the internal drag-truss. Also called "drag strut."

Rib, former or false—An incomplete rib, frequently consisting only of a strip of wood extending from the leading edge to the front spar, which is used to assist in maintaining the form of the wing where the curvature of the airfoil section is sharpest.

Wing skid—See *Skid*.

Wing spar—The principal transverse structural member of the wing assembly of an airplane.

Wing truss—The framing by which the wing loads of an airplane are transmitted to the fuselage. It comprises struts, wires, cables, tie rods, and spars.

Wire—In aeronautics, refers specifically to drawn solid wire.

Wire (airship):

Antiflutter—A wire in the plane of the outer cover for locally reinforcing the outer cover in that part of the airship and reducing fluttering in flight due to air pressure or propeller wash. Also called "outer-cover support wire."

Chord—A wire joining the vertices of the polygonal frame of the main transverse frame.

Diametral—A chord wire which passes through or near the center of the main transverse frame. It is usually attached to the axial fitting.

Fairing—A wire provided as a point of attachment for the outer cover to maintain the contour lines of the envelope of an airship.

Main shear—A diagonal wire taking up mean shear loads in the structure of a rigid airship.

Netting—Diagonal and/or circumferential wire netting fitted between the longitudinals over the entire hull of a rigid airship, to transmit the lift of the gas cells to the structure. Sometimes called "gas-pressure wires."

Radial—A wire which extends from an axial fitting at the center of the transverse frame of a rigid airship to a joint of the frame.

Secondary shear—Additional reinforcing shear wire.

Wire, antidiag—A wire designed primarily to resist forces acting parallel to the chord of the wing of an airplane and in the same direction as the direction of flight. It is generally inclosed in the wing.

Wire, drag—Any wire or cable designed primarily to resist drag forces.

Internal—A drag wire concealed inside the wing.

External—A drag wire run from a wing to the fuselage or other part of the airplane.

Wire, landing—A wire designed primarily to resist forces in the opposite direction to the normal direction of the lift and to oppose the lift wire and prevent distortion of the structure by an over-tightening of those members. Sometimes called "antilift" wire.

Wire, lift—A wire or cable which transmits the lift on the outer portion of the wing of an airplane in toward the fuselage or nacelle. This wire usually runs from the top of an interplane strut to the bottom of the strut next nearer the fuselage. Sometimes called "flying wire."

Wire, stagger—A wire connecting the upper and lower surfaces of an airplane and lying in a plane substantially parallel to the plane of symmetry. Also called "incidence wire."

Wood, laminated—A product formed by gluing or otherwise fastening together a number of laminations of wood with the grain substantially parallel. (Differs from plywood in that in the latter the grain of alternate plies is usually crossed at right angles; also, the plies of the latter are usually made up of veneer.)

Yawmeter—An instrument for measuring the angle of yaw.

Zero-lift line—A line through the trailing edge of an airfoil section parallel to the direction of the wind when the lift is zero.

Zoom—To climb for a short time at an angle greater than that which can be maintained in steady flight, the airplane being carried upward at the expense of its kinetic energy. This term is sometimes used as a noun, to denote any sudden increase in the upward slope of the flight path.

REPORT 240

NOMENCLATURE FOR AERONAUTICS

By THE NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length.....	<i>l</i>	meter.....	m.	foot (or mile).....	ft. (or mi.)
Time.....	<i>t</i>	second.....	sec.	second (or hour).....	sec. (or hr.)
Force.....	<i>F</i>	weight of 1 kilogram..	kg.	weight of 1 pound....	lb.
Power.....	<i>P</i>	kg./m./sec.....	.....	horsepower.....	hp.
Speed.....		km./hr.....	.....	mi. hr	m. p. h.
		m./sec.....	.....	ft. sec	f. p. s.

2. GENERAL SYMBOLS, ETC.

 W , weight = mg . g , standard acceleration of gravity
= 9.80665 m./sec.² = 32.1740
ft./sec.² m , mass = $\frac{W}{g}$. ρ , density (mass per unit volume).Standard density of dry air, 0.12497
(kg.-m.⁻⁴ sec.²) at 15° C. and 760
millimeters = 0.002378 (lb.-ft.⁻⁴
sec.²).Specific weight of "standard" air,
1.2255 kg./m.³ = 0.07651 lb./ft.³ mk^2 , moment of inertia (indicate
axis of the radius of gyration k
by proper subscript). S , area. S_w , wing area, etc. G , gap. b , span. c , chord length. b/c aspect ratio. f , distance from C. G. to elevator
hinge. μ , coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

- V , true air speed.
- q , dynamic (or impact) pressure $= \frac{1}{2}\rho V^2$.
- L , lift, absolute coefficient $C_L = \frac{L}{qS}$.
- D , drag, absolute coefficient $C_D = \frac{D}{qS}$.
- C , cross-wind force, absolute coefficient $C_C = \frac{C}{qS}$.
- R , resultant force. (Note that these coefficients are twice as large as the old coefficients L_C, D_C .)
- i_w , angle of setting of wings (relative to thrust line).
- i_t , angle of stabilizer setting with reference to thrust line.
- γ , dihedral angle.
- $\rho \frac{Vl}{\mu}$, Reynolds Number, where l is a linear dimension; *e.g.*, for a model airfoil 3-inch chord, 100 miles per hour normal pressure, 0° C.: 255,000 and at 15° C., 230,000; or for a model of 10-centimeter chord 40 meters per second, corresponding numbers are 299,000 and 270,000.
- C_p , center of pressure coefficient (ratio of distance C. P. from leading edge to chord length).
- β , angle of stabilizer setting with reference to lower wing $= (i_t - i_w)$.
- α , angle of attack.
- ϵ , angle of downwash.

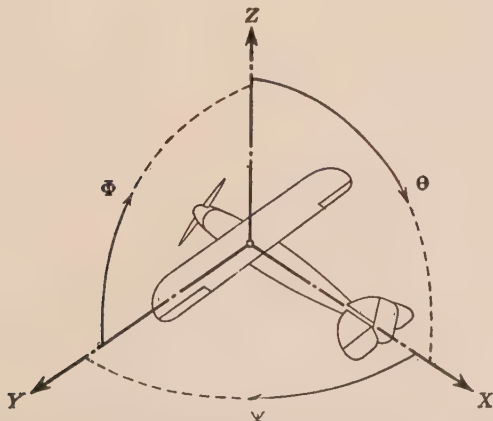


FIG. 1.—Positive directions of axes and angles (focus and moments) are shown by arrows.

Axis			Moment about axis			Angle		Velocities	
Designation	Sym- bol	Force (parallel to axis) symbol	Designa- tion	Sym- bol	Positive direc- tion	Designa- tion	Sym- bol	Linear (compo- nent along axis)	Angu- lar
Longitudinal	X	X	rolling..	L	Y→Z	roll	Φ	u	p
Lateral.....	Y	Y	pitching	M	Z→X	pitch...	Θ	v	q
Normal.....	Z	Z	yawing	N	X→Y	yaw.....	Ψ	w	r

Absolute coefficients of moment

$$C_L = \frac{L}{qbS} \quad C_M = \frac{M}{qcS} \quad C_N = \frac{N}{qfS}$$

Angle of set of control surface
(relative to neutral position), δ .
(Indicate surface by proper sub-
script.)

4. PROPELLER SYMBOLS

D , diameter.
 p_e , effective pitch.
 p_o , mean geometric pitch.
 p_s , standard pitch.
 p_v , zero thrust.
 p_a , zero torque.
 p/D , pitch ratio.
 V' , inflow velocity.
 V_s , slip stream velocity.
 T , thrust.

Q , torque.
 P , power. (If "coefficients" are
introduced, all units used
must be consistent.)
 η , efficiency = TV/P .
 n , revolutions per second, r.p.s.
 N , revolutions per minute, r.p.m.
 Φ , effective helix angle = $\tan^{-1}$
 $\left(\frac{V}{2\pi rn} \right)$.

5. NUMERICAL RELATIONS

1 hp. = 76.04 kg./m./sec. = 550 lb./ft./sec.
 1 lb. = 0.4535924277 kg.
 1 kg. = 2.2046224 lb.
 1 kg./m./sec. = 0.01315 hp.
 1 mi./hr. = 0.44704 m./sec.
 1 m./sec. = 2.23693 mi./hr.
 1 mi. = 1609.35 m. = 5280 ft.
 1 m. = 3.2808333 ft.

INDEX

A

- Accessories for engines and planes, 317
- Aerodynamic symbols, 681
- Aileron control, Waco, 62
- Ailerons, 52
- Air commerce regulations, 589
 - cooled engines, 82
 - four-in-line, 247
 - distance recorder, 387
 - stream on tail surfaces, 48
 - traffic rules, 623
 - transport mileage, 32, 33
- Aircraft inspection, 607
 - instruments, 372
 - lighting, 317
 - marking, 600
 - operation, 608
- Airflow around struts, 49
 - around wings, 2
- Airfoils, 2
- Airplane cabin interiors, 29-30
 - construction, 397
 - engines, 67-279
 - part, name of, 14
 - stick control, 502
 - theory, 1
 - wheel control, 503
- Airplanes, types of, 10
 - Aeromarine-Klemm, 16
 - Bellanca, 16
 - Boeing, 17
 - Curtiss Robin, 17
 - Airplanes, Eaglerock, 18
 - Fairchild, 71, 18
 - Fokker tri-motor, 19
 - Ford tri-motor, 20
 - Gipsy-Moth, 25
 - Ireland flying boat, 21
 - Keystone pathfinder, 22
 - Keystone-Loening amphibian, 24
 - Lockheed Wasp-Vega, 23
 - Simplex, Red Arrow, 26
 - Stearman coach, 26
 - Stinson monoplane, 27
 - Travel-Air monoplane, 28
 - Waco-10, 28
 - Airport, construction of, 544
 - definitions of, 544
 - equipment, 546
 - markings, 547
 - Airports, site of, 545
 - Airship or dirigible, 534
 - characteristics, 541
 - names of parts, 541-543
 - non-rigid, 542
 - rigid, 543
 - semi-rigid, 542
 - Air-speed indicator, 379
 - Alclad, 431
 - Altimeter, 378
 - Attitude, effect on engines, 68
 - Aluminum alloys, 430
 - castings, 436, 473
 - properties of, 434
 - tubing, 435
 - stream lined, 437

A-N standards, 493
 Angle of incidence, 1
 measuring, 45
 Approved certificates, 600
 Ascology, 489
 Atha's 2600 alloy, 489
 Autogiro, Cierva, 13

B

Balancing propellers, 308
 Ball hex bolts and nuts, 530
 Ballonet, 537
 Balsa wood, 478
 Bank and pitch indicator, 386
 turn indicator, 385
 Beacons for airports, 555
 Biplanes, 11
 Blimp, why so called, 537
 Bliss Jupiter engine, 196
 Boeing construction, 402
 Bolts, ball head, 530
 plain hex, 527
 for propeller clamp ring, 495
 Brakes and wheels, 361
 Brasses, characteristics of, 440

C

Cable eyes, 514
 Cables, stranded wire, 38
 Cantilever wings, 11
 Carbureters, 285, 321
 Cadalyte rust proofing, 485
 Calite, 490
 Castings, aluminum alloys, 473, 436
 design values, 461
 Castle nuts, 532
 Certificates of approval, 600
 Challenger engine, 82
 operation and maintenance, 88
 Characteristics of airships, 541

Checking alignment of plane, 46
 Chieftain engine, firing order, 93
 Chord, 2
 Chromel, 490
 Cierva autogiro, 13
 Cirrus, Mark III, engine, 247
 Clamp ring for propeller hub, 495
 Clearances for engines, Challenger,
 85

Le Blond-60, 216
 Warner Scarab, 245
 Wasp, 127

Climbing ratios for clearing obstructions, 568
 Commercial airplanes, 15
 Compass compensator, 383
 earth inductor, 388
 magnetic, 380
 sun, 394
 Construction of airplanes, 397
 Contents of tubes and cylinders, 445
 Control surfaces, 51
 Coolant for engine radiators, 69
 Cord, galvanized, 453
 Cost of engines, 79
 Cowling for Cirrus Mark III engine,
 250
 N.A.C.A. 10, 81
 Wasp engines, 114
 Whirlwind, 136, 159
 Curtiss O-X engines, 253
 Curtiss-Reed propeller, 304
 Cylinders and tubes, contents of, 445

D

Decimal parts of inch, 450
 Delhi rustless iron, 490
 Design values of materials, 454
 Dihedral angle, 5
 measuring, 44
 Dirigible airship, 534

Drift and anti-drift wires, 40
indicator, 391

E

Electric wiring for planes, 396
Engine clearances, Challenger, 85
 LeBlond-60, 216
 Warner Scarab, 245
 Wasp, 127
 cowling, 81
 Curtiss Challenger, 82
 effect of altitude on, 68
 inspection, 293
 reduction gears, 349
 speeds, 67
 starter mounting, 499
 starters, 352
 troubles, 166, 264-270
 and tachometer shaft connectors,
 501

Engines for airplanes, 67-279
 cost of, 79
 Curtiss O-X, 253
 firing order of, 70
 rotation of, 22
 trouble shooting for, 280
 types of, 76

 Cirrus, Mark III, 247

 Curtiss O-X, 253

 Gipsy, 252

 Hispano, 270

 Hornet, 131

 Jupiter, 196

 LeBlond-60, 205

 Velie M-5, 217

 Warner Scarab, 224

 Wasp, 103

 Whirlwind, 132-143

 weight per hp., 67

Etching propeller blades, 311-316

Ethylene glycol as a coolant in
 radiators, 69

Eureka strut sections, 406
Eye bolts, 510

F

Fahralloy, 491
Fairchild wing and rudder, 404
Ferrules and loops, 524
Firing order of engines, 70
 Challenger engine, 82
 Chieftain engine, 93
 Hispano engine, 273
 single row radial engines, 75
Flare for landing, 319
Floats and hulks, repairing, 63
 or pontoons, 366
Flying wires, 61
Fokker wing beams, 412
Folding wings, 414
Ford plane construction, 400
Forks, 521
Four-cylinder in live engines, 247
Fuel flow gage, 378
 meter, 378
 pump, hand, 321
 mounting, 500

G

Gages, fuel-flow, 378
 fuel-level, 376
 pressure, 376
 for wire and plate, 449
Generator mounting, 499
Generators for airplanes, 356
Gipsy four-in-line engine, 252
Glues and glued joints, 481

H

Handling airplanes, 55
Heat resistant alloys, 488

High-wing airplanes, 10
 Hispano engine, 270
 Hornet and Wasp engines, 103-131
 Hubs of propellers, 310-314, 494
 splined, 498
 Hybnickel, 491

I

Ignition, 286
 Incidence, angle of, 1
 Inclinometer, 387
 Indicator, air-speed, 379
 bank and pitch, 386
 turn, 385
 rate of climb, 386
 speed and drift, 391
 Indirect lighting, 395
 Inspecting carbureters, 330
 propellers by etching, 311-316
 Inspection of aircraft, 607
 of engine, 293
 Challenger, 90
 Warner Scarab, 229
 Wasp and Hornet, 118
 Whirlwind, 169-182
 Curtiss O-X, 261
 Installing carbureters, 328
 engines, Hispano, 278
 Wasps, 111
 Whirlwind, 157
 magneto on engine, 341
 Instrument boards, 374
 Instruments, aircraft, 372
 required, 599
 International fuselage, 411

J

Junker construction, 416
 Jupiter engine, 196

L

Landing flare, 319
 gear brakes and wheels, 361
 shock absorbers, 357
 tires, 364
 lights, 318
 strut, Waco, 64
 and take off lengths, 574
 strips, effective, 575
 wires, 39-61
 LeBlond-60 engine, 205
 Lewis supercharger, 69
 Licensing aircraft, 589
 of mechanics, 621
 of pilots, 613
 Lift of wings, 2
 Lift-drift ratio, 4
 Lighting aircraft, 317
 of instruments, indirect, 395
 system for airport, 555
 Lights, instrument board, 395
 landing, 318
 navigation, 317
 Load factors, pounds per hp., 593
 Lockheed fuselage mold, 410
 Loops and ferrules, 524
 wire, good and bad, 37
 Los Angeles at Lakehurst, 536
 Low-wing airplanes, 10

M

Magnesium and its alloys, 438
 Magnetos, 288
 Scintilla, 333
 Marking of aircraft, 600-610
 for airports, 547
 Martin wing beam, 405
 Materials of construction, alclod,
 430, 431
 aluminum alloys, 429, 430
 design values, 454

Mechanics license, 621
 Metal construction, 400
 floats and hulls, repairing, 63
 Mid-wing airplanes, 10
 Mileage of air transport, 32, 33
 Monococque construction, Lock-
 heed, 410
 Monoplanes, 10
 Moss supercharger, 69

N

Names used in aeronautics, 630
 National-Shelby tube, 448
 Navigation light, 317
 Nichrome, 489
 Nomenclature for aeronautics, 630
 Non-ferrous bars, design values, 460
 sheets, design values, 458
 tubing, design values, 459
 Nuts, castle, 532
 plain hex, 529

O

Octant, 393
 Oleo lending strut, Waco, 64
 Operating costs of engines, 80
 Operation of aircraft, 608
 Overhauling carbureters, 330
 engines, Challenger, 94
 Curtiss Ox, 261
 Velie, 221
 Warner Scarab, 230
 Wasp and Hornet, 120

P

Parachutes, 369
 Parasol wings, 10
 Parts of airplanes, 14
 Patches and rivet dimensions, 66

Pilots license, 613
 Pin eyes, 518-520
 Pitch and bank indicator, 386
 of propellers, 307
 Pitot-static tube, 380
 Plywood construction, 473, 478
 wings and beams, 412, 414
 Pontoons, or floats, 366
 Pressure gages, 376
 Propeller, bolts for, 495
 clamp ring for, 495
 hubs, 310-314
 and shaft ends, 494
 symbols, 682
 Propellers, 53-303
 balancing, 308
 inspecting by etching, 311-316
 pitch of, 307
 types of, Curtiss-Reed, 304
 Micarto, 311
 Standard Steel, 306
 Pulleys, non-metallic, 505
 Pump, fuel, hand, 321

Q

Q-alloys, 491

R

Radio for aircraft, 399
 Rate of climb indicator, 387
 Reduction gears, 349
 Regulation for air commerce, 589
 Repairing metal floats and hulls, 63
 Rezistal, 491
 Rigging and servicing the plane, 34
 Rigid terminals, 508
 Riveted duralumin joints, 474
 Rivets for patching metal floats, 66
 Rotation of engines, 72
 Rules for air traffic, 623
 Rust proofing, 484

S

- S. A. E. standards, 493
 - airplane stick control, 502
 - wheel control, 503
 - AN (Army-Navy) standards, 493
 - ball hex bolts and nuts, 530
 - bolts, ball head, 530
 - plain hex, 527
 - for propeller clamp, 495
 - cable eyes, 514
 - castle nuts, 532
 - clamp ring for propeller hub, 495
 - engine starter mounting, 499
 - tachometer connection, 501
 - eye bolts, 510
 - ferrules and loops, 524
 - forks, 521
 - fuel pump mounting, 500
 - generator pump mounting, 499
 - hubs, propeller, 494
 - splined, 498
 - loops and ferrules, 524
 - nuts, castle, 532
 - plain hex, 529
 - pin eyes, 518
 - propeller, bolts for, 495
 - clamp ring, 495
 - limb and shaft, 494
 - pulleys, non-metallic, 505
 - rigid terminals, 508
 - shackles, 506
 - shaft ends, 494
 - taper for, 496
 - shafts, splined, 497
 - splined hubs, 498
 - shafts, 497
 - stick control, 502
 - storage battery, 503
 - tachometer drive, 500
 - shaft connection, 501
 - taper shafts, propeller, 496
 - S. A. E. standards, thimbles, steel, 525
 - threads, 496
 - turnbuckles, 512
 - washers, bevel, 533
 - flat, 526
 - wheel control, 503
 - wire loops and ferrules, 524
- Safe loading ratio, 568
- Scarab engine, 224
- Scarf joints in plywood, 476
- Scintilla magneto, 333
- Screw holding in wood, 477
- Seaplane ports, 567
- Servicing the plane, 34
- Sesqui-wing airplane, 10-13
- Sextant or octant, 393
- Shackles, 506-507
- Shaft ends and propeller hubs, 494
 - taper for propeller hubs, 496
- Shafts, splined, 497
- Shelby tubing, 447
- Shock absorbers, 357
- Silchrome, 492
- Silver solders, 483
- Site of airports, 545
- Solders, silver, 483
 - soft, 481
- Slotted wings, 5
- Special shapes for airplane construction, 463
- Speed and drift indicator, 391
- Splicing cables, 36
- Spliced hubs, 498
 - shafts, 497
- Stability of airplanes, 48
- Stagger of wings, 14
 - measuring, 45
- Stainless steel, 486
- Standards S. A. E., 493
- Starters for engines, 352
- Stearman biplane, rigging, 57

Steel bar, design value, 457
 sheet, 455
 thimbles, 525
 tubing, 442
 design value, 456

Stick control, 502

Storage batteries, 503

Stranded aircraft wire, 452
 wire cables, 38

Stream lined tubing, 437

Stresses in wing wiring, 39

Struts, care of, 41
 interplane, 43

Sun compass, 394

Superchargers, 347

Sweep-back of wings, 14
 Lewis and Moss, 69

Symbols used in aeronautics, 680

T

Tachometer, 374

 drive, 500, 501

 shaft connections, 501

Tail set-up, Waco, 62

 skid shoe, 526

 wheel mount, 357

Taper shafts, propeller, 496

Tension of wires, 38

Terms used in aeronautics, 630

Theory of airplanes, 1

Thermometers, 375

Thimbles, steel, 525

Threads, general information, 496

Timing engines, Challenger, 101

 Hispano, 273

 O-X, 257

 Warner Scarab, 242

 Wasp, 119

 Whirlwind, 134, 190

 magnetos, 338, 341

Tinned aircraft wire, 453

Tires, 364

Trouble shooting for engines, 280

Tubes and cylinders, contents of,
 445

Tubing, aluminum alloy, 435, 437
 steel, 442

Turn and bank indicator, 385

Turn buckles, 35, 512

Types of airplanes, 10
 of engines, 76

U

Udylite rust proofing, 484

Under-carriage, 54-58

V

Velie M-S engine, 217

Venturi tube, 386

Vought wing covering, 413

W

Wabble pump, 321

Waco-10 biplane, rigging, 58

Waco Oleo loading strut, 64

Warner Scarab engine, 224

Wasp and Hornet engines, 103

Washers, 526, 533

Welding, 417

 flame characteristics, 422

 methods, 423

Welds, sample, 423

Wheel control, 503

Wheels and brakes, 361

Whirlwind engines, J-5, 143
 J-6, 132

Wiley landing flare, 319

Wind cones, 549

- Wing beam of metal, Martin, 405
 - rigging, Waco, 59
 - span, 472
 - wiring, stresses in, 39
- Wire loops and ferrules, 524
 - good and bad, 37
 - strand, 452
- Wires, landing, 39, 61
 - tension of, 38
- Wiring diagrams, Curtiss O-x, 259
 - Hispano, 275
 - Wasp, 109
 - Whirlwind, 154
 - for plane lights, 318
 - for planes, 396, 399
- Wood under stress, 41
- Woods, design values of, 462
- Wright biplane, 1908, 12

